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ABSTRACT

This book contains the proceedings of the Third Topical Conference of Department Chairs in Physics. Topics of the papers summarized include: (1) research centers sponsored by the National Science Foundation; (2) physics programs at the undergraduate and graduate levels; (3) the use of accelerators in education and research; (4) approaches to problems in physics education; (5) physics for women and minorities; (6) preparing undergraduates for graduate school; (7) interdepartmental cooperation; (8) effective teaching; (9) strategies for building graduate education for the future; (10) reversing the declining enrollment trend in physics education; (11) physics education for non-majors; (12) computer uses in physics education; (13) the participation of undergraduates in physics research; and (14) academic research issues. Also included are the program of the conference, a list of participants, and a summary of the conference. (CW)

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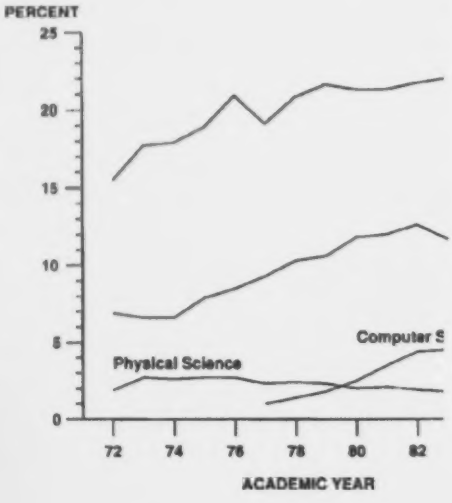

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AAPT Conference of Department Chairs in Physics:

Physics for the 1990s

February 19–20, 1988

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Mark N. McDermott and
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Topical Conference of Department Chairs in Physics

Physics for the 1990s

Program

Friday, February 19, 1988

8:30 a.m.	Plenary Session I Chair: Mark N. McDermott, University of Washington Chair, Steering Committee
Welcome	James A. Krumhansl, President-Elect APS Robert Resnick, President AAPT
Talk	Harold P. Hanson, Executive Director, Majority Staff House Committee on Science, Space, and Technology "University Science Facilities – Status and Prospects" Questions and Answers
Talk	Alan I. Leshner, Director, Office of Science and Technology Centers Development, National Science Foundation "Centers – An NSF Priority" Questions and Answers
10:15 a.m.	Coffee
10:45 a.m.	Plenary Session II Chair: Donald F. Holcomb, Cornell University
Talk	Homer A. Neal, Chair, Department of Physics, University of Michigan "Issues for Undergraduate Physics Programs" Questions and Answers
Talk	Martin Perl, Professor, Stanford Linear Accelerator "Graduate Education and Research in the SSC Era" Questions and Answers
12:30 p.m.	Luncheon
2:00 p.m.	Plenary Session III Chair: Jack M. Wilson, University of Maryland

Talk: Kenneth Ford, Executive Director, American Institute of Physics
"Some Physics Education Issues and Initiatives 1988–"
Questions and Answers

2:30–4:00 p.m. Group Discussion Meetings I

Group A: Recruitment and Teaching of Women and Minorities in Physics
Chair: Demetrius D. Venable, Hampton Institute
Expositor: Elizabeth S. Ivey, Smith College

Group B: Undergraduate Physics Education – Do We Need a New Curriculum for Graduate-Bound Majors?
Chair: Rexford Adelberger, Guilford College
Expositor: Donald F. Holcomb, Cornell University

Group C: Interdepartmental Relationships with Physics – Cooperation, Co-existence, or Conflict
Chair: Sallie A. Watkins, American Institute of Physics
Expositor: John T. Park, University of Missouri

Group D: Teaching Effectiveness – Output Measures Local and National
Chair: Phyllis J. Fleming, Wellesley College
Expositor: J. Woods Halley, Jr., University of Minnesota

Group E: Faculty and Graduate Students in the 1990s – Stockpile One and Import the Other?
Chair: Robert B. Hallock, University of Massachusetts
Expositor: Beverly Fearn Porter, American Institute of Physics

4:30–6:00 p.m. Group Discussion Meetings II

Group F: The Decline of the Physics Major – Strategies for Reversal
Chair: James R. Crawford, Southwest Texas State University
Expositor: Robert L. Micher, Purdue University

Group G: Undergraduate Physics Education – Curriculum for Non-Graduate Bound Majors
Chair: Richard R. Patty, North Carolina State University
Expositor: Edward W. Thomas, Georgia Institute of Technology

Group H: The Computer in Graduate and Undergraduate Education – Better Education or Just More Computers?
Chair: Raymond A. Sorenson, Carnegie-Mellon University
Expositor: Priscilla W. Laws, Dickinson College

Group I:	Undergraduate Education – Research Participation Chair: Robert E. Warner, Oberlin College Expositor: Jerry Gollub, Haverford College
Group J:	Calculus for a New Century – Shall We Get Involved? Chair: Peter Beckmann, Bryn Mawr College Expositor: Jack M. Wilson, University of Maryland
6:00 p.m.	Conclusion of Afternoon Program
6:30 p.m.	Reception and Cash Bar
7:30 p.m.	Dinner Chair: Robert Resnick, Rensselaer Polytechnic Institute
Talk	John S. Rigden, Director of Physics Programs, American Institute of Physics "Rabi" Questions and Answers

Saturday, February 20, 1988

8:30 a.m.	Reports from Discussion Groups
10:30 p.m.	Coffee
11:00 a.m.	Plenary Session IV Chair: Mark McDermott, University of Washington, Chair, Steering Committee
Talk	Robert K. Adair, Chair, Physics Section, National Academy of Sciences and Department of Physics, Yale University "Skirmishes on the Research-Education Border" Questions and Answers Final comments, suggestions, and observations
12:00 p.m.	Adjournment

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Introduction

Mark McDermott

Chair, Steering Committee

University of Washington

The attendance as well as the interest and enthusiasm shown at the Third Topical Conference of Department Chairs in Physics suggests that chairs share many common concerns and find it useful to meet periodically to discuss them. The conference, held February 19–20, 1988, at the Key Bridge Marriott in Arlington, Virginia, was attended by 176 chairs, their representatives, and guests. It was the largest attendance in the series of conferences. A breakdown of the attendance gives an interesting perspective on those who chose to come. Sixty percent were from institutions that offered the B.S. or M.S. as the highest degree. A conclusion that Ph.D.-granting institutions were underrepresented would not be correct because they are outnumbered among schools with physics programs almost 3.5 to 1.0 in the United States. As it was, the mix between Ph.D. and M.S. and B.S. degree-granting institutions seemed about right. Although problems differ between the two groups, many issues such as the preparation of students for graduate work are common. Both groups benefited from the firsthand exchange of represented views.

There has been some feeling that the meeting should move around the country to give greater access to those for whom a trip to Washington, D.C. is a considerable effort. The opposing argument is that the D.C. area site gives greater access to the federal agencies, Congress, and the professional societies. A questionnaire distributed at the meeting showed an overwhelming preference for D.C. among those attending. To counter the criticism that this is a highly biased sample, one can appeal to the geographic distribution of those attending. Although the largest group, 44%, came from states within 300 miles of D.C., 36% were from states 300 to 1000 miles away, and the remaining 20% were from states over 1000 miles from Washington, D.C.

Another interesting set of statistics that is dependent on the drawing power of the conference and the longevity of individual department chairs is the number of those in attendance who had been at the earlier department chair conferences. The count reveals that 35 attendees were at the 1983 conference, 48 at the 1985 conference, and 24 at both. From a partisan perspective this would appear to be one more bit of evidence for the perceived relevance and utility of a conference of chairs.

The format of the conference changed only slightly from that of the 1985 meeting. After rousing welcoming remarks by Jim Krumhansl of APS and Bob Resnick

of AAPT, the assemblage was treated to a series of talks on issues of current interest to physicists. It would be superfluous to summarize them here as they are reproduced in their entirety later in these proceedings. It might be useful to highlight, however, a few of the issues presented. For example, within these proceedings you will find excellent suggestions for increasing the effectiveness with which physicists deal with Congress. Harold Hanson, a Congressional staff member who is also an experienced physicist/administrator, addresses this topic. Also, you will find a status report as of February 1988 on the NSF struggle to establish a Science and Technology Centers program as presented by the director of the program, Alan Leshner. Homer Neal, a new department chair and chair of a National Science Board Task Committee on Undergraduate Science and Engineering Education, describes what needs to be done for undergraduate physics programs and how limited a start has been made. Martin Perl, a distinguished particle physicist and unabashed advocate for particle physics, describes the style of high energy physics and defends its place in academe.

After a description of the efforts of AIP on the education front given by AIP Director Ken Ford, Friday afternoon was devoted to group discussions. Five concurrent topics for the first hour and a half were followed by five more. You will be able to get some flavor of the discussions in the group reports published in these proceedings. These reports were obtained with the help of attending chairs drafted as reporters. The focus and success of the groups rests first with the expositor and chair of the group and then with the chairs attending. Most discussions were called for time and were often continued in the corridors afterward. If there was any persistent complaint about the meeting, it was that not enough time was given to the discussions and that the arrangement permitted easy attendance at only two discussion groups.

The fine banquet in the evening was capped with a warm and personal presentation by John Rigden of his memories and the results of his research on the life and physics career of I.I. Rabi. These are not presented here because we could not do justice to the anecdotes and the style of their presentation in the limited space available. However, for those who have not yet done so, we recommend that you read the fine biography of Rabi by John Rigden, *RABI*, recently published by Basic Books, Inc.

The Saturday morning session was, in part, devoted to reports by the various discussion groups to the whole body. In a number of instances groups felt strongly enough about issues to bring them to the conference in the form of a resolution. These resolutions can be found within the reports of the group which proposed them. They are worthy of special attention because they point out areas of concern to physics departments as seen by their executive officers. Robert Adair, Chair of the Physics Section of the National Academy of Sciences and Sterling Professor of

Physics at Yale University, ended the session with a rousing challenge to university and governmental administrators to lower their costs.

I hope you find this partial record of a series of very interesting discussions and talks an inspiration in your efforts to meet the challenges and problems described. The success of the conference is owed primarily to the lively participation by 176 very interested chairs and guests. On behalf of the Steering Committee, I want to thank Sallie Watkins, AIP, upon whom so much of the burden of organizing the conference fell. I also want to thank Jack Wilson and his able staff at AAPT for making all the arrangements for another smooth-running conference at the Key Bridge Marriott.

Opening Remarks

Third Topical Conference of Department Chairs

Robert Resnick

Rensselaer Polytechnic Institute

When I assumed the Presidency of the AAPT last month, I went back and reread the history of the Association. It is of interest to note that the AAPT was formed officially in 1930 by physicists in the American Physical Society who were unhappy with the lack of attention given to education by the APS. The APS took a narrow view of its role in the early years; applied physics and even fundamental physics related to applications suffered much the same neglect as education. In fact, the Optical Society came into being in 1916 in large part due to this same reason.

What a welcome change then – as this conference itself illustrates – that APS and AAPT are working together closely now on matters of physics education, using whatever special interest, expertise or influence they might separately have.

During my career there have been two long periods of especially close cooperation – each corresponding to a perceived crisis – with the AAPT, as the professional society directly involved in matters of education, usually taking the lead but with strong input and support from the APS. One was the Sputnik–post–Sputnik era (1956–1968) and the other is one that we are in now which some characterize as the international economic competitiveness era.

During this era, the APS formed a Committee on Education that has been in existence now for over a decade, its tempo of activity increasing steadily. I served on that committee under the very able leadership of Judy Franz and then of Ken Ford. Today, with Lillian McDermott as Chair and the appointment of Brian Schwartz as APS Education Officer, that committee is larger, stronger and more active than ever.

We (APS and AAPT) have discovered not only large common areas of direct interest – related perhaps to the overlap we share in the membership categories of college and university physicists, but also the strong coupling between the needs and interests of the groups in which we separately have greater strength – such as industrial and government physicists in the APS and the high school and junior college physicists in the AAPT. Indeed if you look at all the issues on our agenda here, both in plenary sessions and group discussion meetings of "Physics for the 1990s." I am sure that you will not need a flow diagram from me to see how interconnected they all are – whether the coupling is direct or indirect.

We are all bound together, in fact, by the education process. For example, without high school physics teachers and attention to the teaching of physics there (and general science even earlier), our base erodes seriously for students in introductory college physics; that forms another base which leads to physics majors who go on to become graduate students and then the Ph.D.s needed as research

physicists and university faculty. We must nurture the whole process every step of the way – lest we all starve eventually.

Indeed, to give another example, it works the other way as well, when we examine the content of our courses and educational programs. I recall from my direct involvement in the post-Sputnik era how, after 50 to 75 years from the time of origin, we finally brought Maxwell's equations and relativity theory into the introductory college course and exposed more clearly than before in that course the structure and the process of physics. Today we see a similar but shorter-term process as computational physics – starting from research needs and already proceeding to a separate identity in our graduate programs – works its way into our undergraduate programs and even finds groups (such as that headed by Jack Wilson and Joe Redish at the University of Maryland) pushing to get it into our beginning courses.

I recall that in the early 50s at the University of Pittsburgh, the graduate faculty argued as to whether or not quantum mechanics should be a required course for the Ph.D. program (biophysicists and crystallographers were then opposed to this). Quantum mechanics is now not only required for an undergraduate physics degree, but it's already in the sophmore year physics program at RPI and other institutions. And as quantum physics has already long since invaded our introductory course in a qualitative and applied way, we now have an AAPT/APS sponsored program (IUPP, headed by John Rigden) that is examining, amongst other things, how we might begin to get quantum mechanics itself into that course. (Amongst other things includes what to drop out.)

These examples of change and/or progress that come about over a long time period give us some perspective, perhaps, on the ever present clash between inertia and calls for revolutionary change, or the clash between those who would teach physics just the way they learned it as a student 30 or more years ago and those who desire to represent accurately in the introductory course what current research physicists actually do and how they think. Most of the issues we deal with directly here are short or medium term, by comparison, of course. I suspect, however, that indirectly at least – through the direction we set, for example – they can have long term consequences as well.

In any case, you can see that we need one another. Research physicists understand the value of AAPT-initiated programs, like the Physics Teaching Resource Agents, the Physics Olympiad, the Conferences on the Teaching of Modern Physics and others, and teachers appreciate the importance of issues such as those Jim Krumhansl has raised.

One effective technique we have used to make advances is to hold conferences in which we bring together persons who have been grappling with their problems individually to discuss and work together on the solutions. Such conferences serve to raise consciousness, enlarge the pool of active participants, accelerate the consideration of change, generate new ideas or new materials, and lead to action sooner than would take place otherwise. The Topical Conference of Departmental Chairs

– of which this is the third – is an excellent example. Though I have not been a departmental chair, I have been at all these conferences in one capacity or another. Many have told me of the sense of community that beleagured chairs have acquired as a result of such conferences or of new insights or ideas they have gained, not to mention information acquired. They are less aware perhaps of how effective and timely some of our group actions have been.

For example, it is not an accident that, between the time that the department chairs at the first conference passed without dissent a resolution calling upon AAPT, AIP, APS and NSF to work together to gather information and redress the severe need for laboratory equipment and the time that the proceedings of that conference were published, Congress directed the NSF to establish a laboratory equipment program for the four-year institutions. Or again, at the second Chairs Conference, I reported on a survey I conducted of physics department chairs for the APS Education Committee (with strong AIP and AAPT assistance) on the impact of undergraduate physics programs on the quality and quantity of physics majors. That report (it's really yours) became the explicit basis for a National Science Board presentation given in 1986 by the then Presidents of the AAPT (Anthony P. French) and APS (Robert Wilson) on federal support for university science education. The recommendations were endorsed almost in their entirety by that Board and have led to a large increase by Congress to the NSF for spending in post-secondary (i.e. undergraduate) science education. The timing could hardly have been better. These, of course, are only some of the positive outcomes of your conferences – I am sure we could cite many more – general and specific, short term and longer.

So, as President of one of the sponsoring organizations, I welcome you all to the Third Topical Conference of Department Chairs. I expect that on both long-term and short-term issues we will make progress here, some of which will become evident to us at the future fourth conference.

However, I cannot leave you without giving a commercial message – not for my textbooks – but for the AAPT. As department chairs, you really owe it to your faculty and students that your library subscribe to our journals – *The Physics Teacher* and the *American Journal of Physics*. They are highly regarded publications that relate to much of what brings you here today – for information, thought, and study. And, if you do not already, you should yourself belong to the AAPT and should encourage your faculty to do the same. Our services, activities, and programs have never been as broad, as deep and as relevant as they are today. You should be aware of all that. You will be hearing from me soon in that regard.

For now, welcome and good luck in your deliberations.

Remarks before the Third Topical Conference of Department Chairs in Physics

Harold P. Hanson

Good Morning. I should tell you that Jack and Mark and I were hoping to have Congressman Roe at the podium this morning; they may even have led you to believe he would be here. However, I am functioning, as I often do, in the parlance of baseball, as his designated speaker.

I have no doubt that you would rather have the Congressman up here, but as department chairs, I am sure you have learned to deal with disappointment.

It is probably appropriate that I talk to this group. Back in my days as an honest scientist, I became suddenly, and served for eight years as, the Chair of the University of Texas Physics Department. From the listing you heard from Mark, I am the anthropomorphic embodiment of the ergodic theorem of statistical mechanics which assures us that if you live long enough, everything possible will have happened to you. Thus, I too was a Physics Department Chair at one time.

I think of those days with nostalgia. I believe that the most satisfying and most successful administrative activity I have been involved in, occurred during those years from 1961–1969. The time was right in Texas and the time was right nationally for Texas to make a move. The secret of success is so often a matter of timing rather than talent or effort. I offer this homily before I get into my talk so that when you hear that there is not going to be a great deal of loose change lying around, you will not think any lack of success on your part is necessarily your fault.

As Caesar observed about Gaul, my talk this morning is divided into three parts. First, I will give a short course, a very short course, in the political science of science. Next, I shall talk about (1) the President's asking budget for 1989 that we received yesterday, and (2) where we stand on the possibility for having funding available for bricks and mortar and equipment for science study. Finally, I want to give you a few hints on how you too can have an effect on legislative matters.

First, the short course. The Congress does its work through committees. In the House of Representatives there are 22 standing committees including such things as Armed Services, Agriculture, Commerce, and so on. Unlike university committees, Congressional committees actually do something. I happen to be the Executive Director of the staff of the Science, Space, and Technology Committee of the House of Representatives, and we serve at the pleasure of Chair Roe. We have authorizing responsibility for all non-military and non-biomedical research that the Federal Government supports. That leaves out some things that are mighty significant – but it also includes much – like NSF, NASA, NBS, DOE basic research, EPA basic research, and others as well. Additionally, our oversight responsibility extends to all phases of governmentally funded research.

Most of the work of any Congressional committee is carried out by subcommittees. I often make a comparison of the functioning of a college and its departments to the working of the committee and its subcommittees. The subcommittees are like college academic departments. In both instances, that is where the action is. That is where the quality of life is determined. The subcommittee staff directors are like department chairs. And the good ones are equally as mean, selfish, and aggressive as their academic counterparts, namely you. By analogy, I function as the dean of this special college – and if you have ever figured out what a dean does for a college, that is what I do for the committee.

You will note that I said our committee authorizes funding. There are two levels above us that have greater control, or at least a different kind of control. First, there is the Appropriations Committee which may or may not appropriate the funding our committee authorizes. And in some instances where we are not specific or timely, the Appropriations Committee has been known to shape and modify our authorization – that we do not like very much.

Futhermore, in these days of Gramm-Rudman, the level above the appropriations level is being felt more than ever. In general, the Budget Committee may or may not create a budget which conforms to the appropriations and authorizations. Further, within broad categories, they too may shape or modify our priorities. In principle, there is an orderly sequence to all this. In practice there is always creative tension, if not outright confusion. Add to this a disoriented Senate and doctrinaire President and it is a wonder that the nation ever gets a budget. As a matter of fact, we do not get a budget. We only get an omnibus continuing resolution which is a wonder in itself.

When I agreed to be involved in your morning's activities, the game plan was in part for me to discuss the President's asking budget for 1989. At that time, the budget was to come to us the last week in January. The way things worked out we received the OMB budget just yesterday, and there is no responsible way that I could tell you that we have vetted it. I can tell you that it is apparently put together with the same cynical technique that has marked all the Administration budgets since I took my present job in 1980.

The budget appears quite favorable to science, but it cuts or eliminates programs which the OMB knows without question will be restored. This is an age-old device practiced at the city, state, and national level. Here we call it the Washington Monument Gambit, wherein the National Park Service responds to budget cutting by announcing it will be necessary to close the monument on July 4th.

But before I tell you what little I know about the '89 budget, let us see what happened to the '88 budget. We will start with the NSF budget because that has the interest of most of you.

In a speech I made about this time last year, I said that we were dealing with a good news/bad news story that was not a joke. The good news was that the Administration's proposed science budget was very gratifying to scientists. The bad

news was that we would not get the Administration's budget. For a brief heady moment during the year I thought I might be wrong and that the NSF was due to get an auspicious start in its program to double its budget in five years by getting a 17% increase. When the Gramm-Rudman effect inexorably entered the picture, NSF received only a 5.8% increase to $1.717 billion, although science/engineering education did go up 41% over the 1987 level.

NASA was also a loser, although it is a little hard to figure. NASA's budget went down from $10.5B to $8.8B but a lot of that is accounted for by an emergency Shuttle appropriation for the preceding year. The Space Station got $450 million which keeps it alive – but just barely.

The DOE got an increase over the President's request, but a lot of it was restoration of energy programs the White House always tries to down-size and basic sciences suffered in the process. The SSC got $25 million, as I recall.

So what about the '89 budget? As I see it we have:

Budget Function 250 Budget Authority
(in billions of dollars)

	'88 Req.	'88 Appro.	'89 Req.
NSF	1.90	1.71	2.0
DOE (Gen.Sci.)	0.80	0.80	1.1
NASA	9.50	8.95	11.49
Total	12.20	11.46	14.74

Unfortunately, the $3B increase is what the overall budget agreement between the House, the Senate, and the White House provided for the whole discretionary domestic budget. Never believe we will get the whole budget increase for our own programs.

Now let me say something about the Facilities Bill. Without straining your credulity or my modesty too much I think that I was the instigator of the present set of facilities bills.

As a Department Chair I had been able to get my hands on a small amount of that last facilities money that NSF was giving out when the nation was hyperventilating over Sputnik. I knew how crucial that had been in our getting state appropriations for a new physics-astronomy-math building. That funding program evaporated a decade and a half ago and as I saw it, the need for science research facilities had grown acute. I told Don Fuqua, the previous chair, that if he wanted to leave a mark he should do two things: introduce a facilities bill and a bill for the cautiously sensible release of genetically altered species into the environment. So these bills were crafted and introduced. But it is a long way from introducing a bill,

and even holding hearings on a bill – a long way to passage of that bill. Nothing much happened in Congress and Fuqua retired. I made my same pitch to Congressman Roe and there is a Roe Facilities Bill, H.R. 1905. There is a companion bill in the Senate. The bill is changing from my original conception as being research-oriented to one that will also address the building and science-equipment needs of community colleges, traditionally black institutions and liberal arts colleges. A rainbow coalition. I have not lost my enthusiasm for the effort because I am for anything that advances higher education.

The status is the following: The Roe Bill is now imbedded in the omnibus Trade Bill which is intended to address the problem of competitiveness.

The House version of the Trade Bill (H.R. 3) contains two sections relating to academic research facilities. The Senate version does not contain any such provision. The first provision amends the Higher Education Act of 1965 by adding the "College and University Research and Instrumentation Modernization Program." This competitive grant program, administered through the Department of Education, is identical to H.R. 1905 in its structure (including a 20% set-aside for smaller institutions) but much smaller in authorized funding. H.R. 3 authorizes $55.0 million in Fiscal Year 1988 and "such sums as may be necessary" for succeeding years. The second provision sets up a similar program in the Department of Education targeted to academic research programs that specialize in agriculture, strategic metals, minerals, and forestry. This program is authorized for $20.0 million in Fiscal Year 1988 and "such sums..." for future years. The House leadership has declared its intention to bring the Trade Bill Conference Report to the House Floor no later than March 23, 1988.

Let me finish up by giving you a little primer on how you too might influence the system. I want a show of hands on this. How many of you are going to visit your Congressman on this trip to Washington? In general, physicists have been in the game longer than other scientists and some do a good job of it. I will not use the demeaning L-word, but you do know what I am talking about. It goes by the euphemism of "education" – something we are all interested in and support. Many of you will be or ought to be involved in this activity, yourselves, so you should be aware of what constitutes good form. My Ten Commandments for academics who want to influence Congress are:

1. Thou Shalt Know Your Congressman

Get to know the Congressman or Senator from your district or state on a personal basis. Get close enough to him that he knows your name and who you are, and what organization, lab, or school you are with. For the most part that will be easier than you think.

2. Thou Shalt Know About Your Congressman

Get to know about him so that you do not commit a faux pas that will damage your basic cause. For example, do not rail against pork-barrel politics when you are there trying to bring home a little bacon of your own. It is not likely that the

Congressman will have the same liberal views that you do, and his general voting record might be other than you would like. However, the only voting record that counts, at the time, is the one he will make on the issue you are pressing.

3. Thou Shalt Not Limit Visitations To Crisis Situations

Make sure that some of the visits are just attitude-enhancing efforts. Visit often for a "hi" and a handshake. The influence you have will fall off inversely as some high power of the length of time between visits.

4. Thou Shalt Know The Congressman's Staff People

The Congressman is the one who gets elected and re-elected on the basis of how well he represents his constituency on the various issues with which he is confronted. Nevertheless, all Congressmen need help in dealing with the vast plethora of problems. It is the Congressman's staff that supply that help. Educating the staff may be as significant as educating the Congressman – and staffers can usually give you more time than the Congressman can.

5. Thou Shalt Have A Focused And Concise Message

The Congressman has even less disposable time than you do. So do not overburden him with detail and do not protract the session. There may be no points to be gained by finishing on schedule, but there are definitely points to be lost by not finishing in the time you have been allotted. Some of the detail, so near and dear to you, can possibly be shared with the staff.

6. Thou Shalt Not Vilify Other Protagonists or What They Represent

Be positive about your own shtick, and do not attack another program unless the Congressman asks you to make a comparison. Recently, a university president was testifying very effectively for a particular academic program when he chose to point out that the program could be paid for very nicely by not building a few submarines – or "holes in the water" as he called them. He immediately lost the affections of the Congressmen that he had been influencing so very effectively. A great number of the Members are dedicated to a strong defense. They might have to make a choice, but they do not want any academic intellectual telling them what an easy and obvious choice it is.

7. Thou Shalt Visit The Congressman in His District

When he is not in Washington politicking, he is in his district politicking, and there are ways of showing him at home that there are real votes involved.

8. Thou Shalt Get to Know Who the Key Congressmen Are

Know who they are in terms of major committee assignments, and make liaisons with other scientists who are in the districts served by these key Congressmen.

9. Thou Shalt Accept a Turn-Down or Set-Back Graciously

Recognize that, when the Congressman votes contrary to your urging, it may well be that it is not because he is ignorant or uninformed. Perhaps his philosophical priorities are different than yours, and, of course, it may be that political considera-

tions dictate a certain vote. That is not always easy for dedicated academics to accept, but it is wisest that you do so. And then keep on trying, in a pleasant fashion, to get him to vote the way you are convinced is right.

10. Thou Shalt Not Do Thy Lobbying Like A Lobbyist

Your competitors for the Congressman's attention and vote are professionals with beaucoup bucks at their disposal. Therefore you should forget about inviting him to lunch – or any other blandishments. He has many more invitations than he can accept and he has very little time. Just know your facts and be prepared to answer tough questions sometimes innocuously put. Be as straight as you know how to be in making your case, and do not underestimate what the Congressman may already know about your problem.

Centers—An NSF Priority

Alan I. Leshner

Office of Science and Technology Centers Development
National Science Foundation

Although Alan Leshner was not able to provide a paper for these proceedings he did furnish us with copies of his viewgraphs and advised us that we could make "whatever use of them you see fit." The subject is of sufficient continuing interest that we will take him at his word and present a selection of the viewgraphs together with our commentary. The commentary is **NOT** to be taken as a paraphrase of remarks made by Leshner at the conference, but as our reaction some months after his presentation. It should also be noted that he included a presentation of the President's budget for the NSF which had just been released at that time. This will be included below with a comparison to the budget which was eventually adopted by Congress.

As described in NSF publications, the Centers Program is a Pan-Foundation program which will support the establishment and operation of a series of Centers in universities. These Centers will involve faculty and students, possibly together with scientists for National Laboratories and Industry, in work on problems or topics best handled by large ($0.5M-$5M/yr), stable (up to 10-year lifetime) groups with diverse experiences and expertises. Leshner's viewgraphs and our commentary follow:

NSF SCIENCE AND TECHNOLOGY RESEARCH CENTERS

NSF S&T Research Centers Program Responds to Multiple Needs:

Large equipment and major facilities

Collaboration across fields

Reliable and stable support

Facilitate transfer of basic knowledge to applications

Improve and expand education for future scientific and technical workforce

NSF S&T Research Centers Program Objectives

Exploit opportunities in fundamental science and technology

Increase transfer of knowledge from discovery to application and among sectors of society

Provide special educational opportunities for future scientific and technical workforce

One of the interesting issues then and now is the extent to which the S&T program would reduce individual investigator support. The following statement was presented as the view of NSF: "STC support is intended to complement, not substitute for, regular individual research project funding."

We submit that the truth of this assertion is nearly impossible to establish. NSF did receive an increase in its overall budget; however, the increase in the Physics Division was tiny, well below the increase in research costs. The amount going to Centers is yet to be determined. However, we will give you some figures which bear on the issue and let you be the judge when the Centers and their budgets are announced.

A description of the process by which proposals were to be submitted and judged was given. Briefly, an unlimited number of proposals were allowed from all institutions. These were classified by the NSF and reviewed by mail and by panels in 14 areas. A much smaller number of proposals were selected for site visits and reviewed by a multidisciplinary panel. The panel's recommendation to consider "balance among fields" and "competitiveness" went to the National Science Board for final action.

Since the proposal deadline had passed by the time of the conference, Leshner was able to give the breakdown on the number of proposals received and their review categories.

NSF S&T RESEARCH CENTERS PROGRAM PROPOSAL STATISTICS

Full STC Proposals = 325

Total Requested (5 years)	= $ 4.1B
Average Request (5 years)	= $12.6M
First-Year Average	= $ 2.4M
Number of Institutions	= 125
Number of States	= 42
Number of Signed PIs and Co-PIs	= 678
Planning Grant Proposals	= 275

The breakdown by review category was as follows:

NSF S&T RESEARCH CENTERS PROGRAM – PROPOSALS PER REVIEW CATEGORY

Mathematics	= 21
Computational Science and Engineering	= 12
Cognitive and Information Science/AI	= 32

Computer Science and Engineering	= 17
Condensed Matter/Superconductivity	= 21
Electronic and Optical Materials/Interfaces	= 27
Surface Science, Catalysis and Synthesis	= 25
Polymers/Micro and Nano Structures	= 17
Engineering	= 12
Other Physics/Astronomy	= 29
Geosciences	= 46
Molecular Sciences	= 19
Biological Sciences	= 29
Social and Behavioral Science	= 14

NST S&T RESEARCH CENTERS PROGRAM – DEPARTMENT ORIGINS OF PIs and CO-PIs

Physics	= 54
Computer Science	= 37
Astronomy/Astrophysics	= 14
Biological Science	= 29
Materials	= 14
Psychology	= 14
Chemistry	= 52
Mathematics	= 14
Engineering	= 54
Geoscience	= 22

Subsequent to the meeting, it was announced that 48 proposals had been selected for site visits. Further consideration of the 48 by a multidisciplinary committee chaired by Carl Linebarger (JILA) was to begin in September.

As described earlier, the controversial subject of the NSF FY89 budget and how Centers were to be funded had just hit the press at the time of the conference in the form of the President's budget request. Leshner had several viewgraphs which outlined the situation. We have added two columns to his presentation which describe the budget finally approved by Congress.

The $150M request for Centers was in the form of "obligation authority," i.e., a Congressional promise that this amount would be available over the first years of the program. Since this attempt to obtain separate funding for Centers failed, FY89 Centers costs (yet to be determined) will come from R&RA. The viewgraphs (reproduced in the following tables) gave the plan and rationale for the request for separate funding.

NSF BUDGET SUMMARY – FY 1988–1989 (dollars in millions)

	FY88 Approp.	FY89 Request	FY89 Actual	FY89/88 Change
Research and Related Activities	1,453	1,603	1,583	8.9%
Science and Engineering Education	139	156	171	22.8%
US Antarctic Program	125	141	131	4.8%
Science and Technology Centers	0	150	0	0
TOTAL NSF	$1,717	$2,050	$1,885	9.8%

NSF S&T RESEARCH CENTERS PROGRAM – FY 1989 PLAN

New $150 million appropriation

Up-front, full funding (4–5 years) for about 15 centers

Projected award size: $1–5M per year for up to five years

Slow outlay pattern (over 7–8 years)

NSF S&T RESEARCH CENTERS PROGRAM – RATIONALE FOR THE SEPARATE APPROPRIATION

Clearly separate funding of STC activity from individual investigator support

Provide reliable, stable support for the STC's first years

Demonstrate to potential partners the Foundation's long-term commitment

Take advantage of slow outlay rate

Most of the questions about the STC program remain to be answered. Which proposals will be funded and at what budget level? Will they provide "large equipment and major facilities," promote "collaboration across fields," "facilitate transfer of knowledge," and "improve and expand education" as NSF hopes? Will the program be an add-on or come at the expense of individual investigator grants? A comparison point might be the FY89 budget of the Physics Division. It rose a paltry 1.2% between FY87 and FY88. If you take into consideration the substantial cost of upgrading several major facilities over the same period, individual investigators lost ground.

Whatever occurs, the chairs who attended the conference got an excellent "first look" at the Science and Technology Centers Program through Leshner's presentation.

Issues for Undergraduate Physics Programs

Homer A. Neal

University of Michigan

Introduction

I am pleased to address you today on the issue of undergraduate education in physics. First, I want to publicly declare that I have no particular expertise to bring to you today on this topic. Indeed, I have spent more of my life worrying about graduate education and research that I have on undergraduate matters. But, as fate would have it, as a result of being innocently asked to head up a Task Committee on Undergraduate Education in Science, Mathematics and Engineering for the National Science Board, I was unwittingly led into giving serious thought about the role of undergraduate science education in our overall human resource picture.

In conducting this study for the Science Board, I reflected upon the many occasions where, in former lives as Dean of Research and as Provost, I made decisions at the expense of our undergraduate programs, with the resolute feeling that they were so resilient that they would rebound from any injustice we might inflict upon them. While that may have been true regarding my overall impact as an individual – the possible culminative effect of a lessening of resolve to protect and nurture our undergraduate programs, when viewed nationwide, is frightening.

In my comments today, I will share my views on the health of our undergraduate science programs, highlight where I see problems, suggest solutions, and point out areas of current productive activity.

Importance of a Technologically Literate Society

Over the past decades one could always state that in the coming years technology would be playing an increasingly central role in his or her life. For me to restate that now would hardly offer you any new information. Nevertheless, and once again, the current rate of growth of technology again gives us reason to believe that we are on the threshold of a new era, one in which the need for technological literacy will be overwhelming.

Our medical doctors are being faced with the need to use and interpret data from extraordinarily complex instruments. Engineers are dealing with systems smaller than ever and, simultaneously, larger than ever. Lawyers and judges must rely on technology more and more in the assessment of innocence and guilt. Foodstore clerks have, in many cases, been reduced to dragging groceries past some magical plate of glass. Personal computers have opened up a whole new world of creative possibilities for persons who in the past would not have been able to use a slide rule. Biologists are creating new life forms. And so on. Technology is encircling almost all aspect of life, and there is no reason to think that the pace will slow.

Now technology is not physics. But, at least in the group assembled today, I can say that most of the foundation of technology is physics. The laser readout of the

price of groceries – and laser eye surgery – would be in tough shape without the laser. Personal desktop computers would not be so friendly to one's desk if there were not transistors. NMR medical imaging would not be the success of the day, if there were no NMR. So, the point should be clear that a country that fails to recognize the importance of its physics base is setting a ticking time bomb in the midst of its development plans.

And I have not even mentioned physics for physics sake. Most of us do physics because we want to answer the questions "why" and "how." What we do then stimulates others to ask other questions and to propose other solutions, and so on. In a healthy environment, this process goes on and on, leading both to practical applications and to new avenues of physics.

The high quality training of undergraduates in physics is a major component of the country's effort in sustaining a strong science and technology base. Some of these students become the key scientists, lawyers, doctors, and engineers of the future. They will have an unmistakable impact on our industries and our universities for the decades ahead.

As many of you may be aware, my state of Michigan is one of the states with an SSC site on the "Best Qualified List." Earlier this week we had an official DOE Scoping Visit at our Stockbridge SSC site, and, while in the main the citizen comments there are very supportive, other comments prompt me to say a couple of words here about our responsibility in assisting with the public understanding of science. We do this, of course, by offering classes that are taken by non-scientists; we do it by doing a good job training high school teachers; and we can do it by making ourselves available to public groups. A large fraction of our population simply does not understand radioactivity, for example. And what people do not understand they mainly resist. We have an obligation to do a better job in making sure that our high schools and colleges have the facts regarding the many pervasive elements of our environment that cry out for clear physics explanation.

Elements of an Undergraduate Program

It is easy for one to dissect the various components of an undergraduate program. To have take place the process of education, as we know it, you must have a student and a teacher, and you must have certain tools for them to use. Thus, one could in principle completely describe the sum total of physics education issues by examining the state of the student, the teacher, the curriculum, and instrumentation, and delineating the multi-parameter interactions between each of these entities. In the time available, we clearly cannot do justice to each topic, but I will try to identify some of the major terms in the Hamiltonian.

Students

First, the student. In terms of the majors, we see that we continue to offer an increasing number of bachelor degrees, though the rate of increase has clearly slowed in the last reporting year (1985-86), with an increase of 310 degrees between 1984/1985 vs. an increase of only 26 between 1985/1986. The fraction of the degrees

given to women seems to have declined slightly in the last reporting year (14.4% to 13.8%), and the fraction of blacks and Hispanics has risen from 3.5% to 4.8%.

Over the past 15 years there has been a significant decline (2700 vs. 1700) in the number of U.S. students going into first year graduate studies in physics. Moreover, there are data that indicate that the fraction of the "best and brightest" freshmen students selecting the physical sciences is in a state of general decline. These are issues to be concerned about.

The coming drop in the number of 18-year olds is another item of concern. What will be the impact on our ability to produce the number of bachelors required to meet national needs? What should be the impact on our instructional delivery approach? What will be the impact on the justification of departmental size?

Only 28% of our majors go on to graduate school in physics. The majority of others go to industry, the military, government, and high school teaching. One question that has been raised is whether by pitching our undergraduate programs selectively to our "graduate school bound" 28%, are we rendering a disservice to the 72% who will be entering other avenues. This is an issue that needs to be reviewed.

The Faculty

Now, what about the faculty. In our National Science Board study, we found evidence for a considerable amount of stress within the science faculties across the country. There was concern that "good teaching" was not highly valued by our departments and universities. The internal reward structures did not favor teaching at many universities. Junior faculty were often encouraged not to devote much of their time to instructional development activities. Moreover, there seems to be decline in the number of senior faculty engaged in course and textbook development activities.

At many smaller, non-research oriented colleges there was concern that faculty teaching loads were so high that the faculty had little time to even keep up with the major developments in their speciality. Bright students could read of new developments in a New York Times article that the faculty member was unable to even begin to interpret for them.

Basically, the faculty are dedicated to good teaching, believe that it is important, but confused about institutional priorities, and interpret the low priority given to good teaching in many institutions as an indication that all one needs to do is carry out their intructional duties in a minimal fashion, particularly given other demands.

Frustrations of the faculty in several cases are aggravated by the absence of adequate laboratory and demonstration equipment. This is a problem.

The issue of foreign graduate assistants remains. While certainly not a problem in a majority of instances, there are numerous cases where the quality of instruction, or the perceived quality of instruction, suffers because of language difficulties and cultural differences. With the growing foreign component of our graduate student population, this will continue to be an issue for us.

The Curriculum

The physics curriculum contains its share of controversy. Some physicists say that things are in terrible shape. There are few new and revolutionary textbooks and approaches. The pattern of presenting material is the same in many courses as it was decades ago, in spite of the new computational and other tools now available to the student. Many departments are struggling with the matter of how many semesters to use to cover the introduction sequence, 2 or 3? If it is to be 2, what topics are to be cut out? For those topics cut out, how are they covered later on in the 200–300 levels?

There are, of course, others who argue that things are just fine, and that any efforts to tamper with the curriculum are counterproductive; that there are no days like the good-ole-days. Computers, rather than being viewed as tools to get quickly to the answer of a problem, may be thought of as an obstacle to requiring the student to think about how to get at the answer using physical insight and approximation techniques.

Another area of debate is the utility of the "watered-down" courses. Do we need "Physics for Poets" and courses of this type? Some argue that these courses cheat the student out of learning just what physics is all about, and that these students should be "forced" to take the regular courses so that they can learn how nature lends itself to analysis using the powerful tools of vector calculus, etc. Others point out that, for the students in the target audience, you could not drag them, neither kicking nor screaming, into such a rigorous course, and that the best we could hope for is to have the students so enjoy a "poets" course that they would want later to take another and another course in physics. Perhaps those could include a course on "The Physics of Music," or a course on "Energy and the Environment," etc.

In preparation for my presentation I reviewed the catalogs of several universities, with an eye toward picking out physics courses that might lie outside the "core" offering. Some examples of my findings are included here, for the purpose of showing the rich diversity of approaches.

Illinois has a very broad and interesting set of courses, including Practical Physics: How Things Work; Physics and the Modern World; Physics of Photography; Nuclear Weapons, Nuclear War and Arms Control; and Space, Time and Matter. Columbia offers a course on Physics in the Historical Perspective. Princeton offers few special courses, but requires two junior year papers from its students, one on important developments in physics, and one on current research in the department. In addition, it requires a senior thesis.

Stanford offers courses entitled Symmetries in Nature; Physics of Music; Cosmic Horizons; Nature of Technology, Mathematics and Science; and Technology and National Security. At Caltech, there is a computational physics laboratory.

The particular approach used – a rigid adherence just to the basic courses, or a broad array of special courses in addition to the core, or a core plus a very limited number of special courses – all depends on institutional tradition and the views of

the faculty as to what is the best for their students. Each approach, obviously, can work, but each requires the careful attention of the faculty.

These are indeed important issues, and I am pleased to note that some of them will be discussed by the working groups during our meeting.

Every Chair's Nightmare

Imagine for a moment that your institution's brightest senior student was selected for an appearance on a physics talent show, where he or she had a chance at winning a $1,000,000 prize. To do this, the student would only have to answer (on nationwide TV) a series of rather simple physics questions posed by the moderator. One question is "what is a cross section?" The student answers that he or she recalls coming across the term in a biology class, where they had to section a specimen before looking at it under the microscope. The moderator then asks "what do nuclear physicists do," and the student answers that they operate nuclear reactors. The student is then asked a simple question about statistical mechanics and responds by saying he never took shop in high school. To another question, this time on special relativity, the student exclaimed that it had to do with the ages of relatives in a family (especially twins) who had been on a long trip. In exasperation, the moderator gasps, "what school do you go to?"

Could this happen to one of your students? I am assured from discussions with some faculty that many curricula would indeed permit a student to get a bachelor's degree without ever really having to calculate a cross section, to take a course in nuclear physics, to take a course in statistical mechanics, or to have more than 1-2 weeks of special relativity.

One reason for such an occurrence is that many departments make little or no effort to indicate what should be taught in its courses and, under the pressure of time, one professor may eliminate one essential topic to accommodate another, while assuming that the student will pick up the missing part in a subsequent course – and that never happens because in the next course the professor makes the assumption that the student had already covered the topic. Departments need to be careful about coordinating their key courses, at least in general terms.

Instrumentation

Physics is an experimental science, and thus the availability of appropriate instrumentation is an important instructional issue. The right equipment is required to drive home a particular concept in a lecture or laboratory setting. Likewise, in our training role, we need to teach all of our students the fundamentals of experimental techniques, the care required in collecting, analyzing, and interpreting data. There are two extremes in selecting the proper equipment for instructional purposes in physics. It is possible to get equipment that is so sophisticated that the student only pushes buttons and the answer pops out at the other end, with the stu-

dent not really knowing what has happened in the interim. Another extreme is to have dilapidated equipment that does not perform as it should and is successful in so frustrating the students that all of their worst fears about physics are confirmed.

Our National Science Board Committee received testimony from the Presidents of the APS and AAPT (Wilson and French) that stressed the need for additional instrumentation in the undergraduate programs, both for the introductory and advanced laboratories. This is indeed a critical need. In a related study for engineering, an estimate was developed that the needs in engineering nationwide totalled approximately $2 billion. We have no comparable study for physics, but the funding required to modernize our instructional laboratories is also huge. This is another issue requiring continued attention.

The challenges out there are awesome. We should never let down our guard regarding the health of our undergraduate programs. They can be simultaneously robust and fragile.

Next I would like to address some related issues.

The Best and the Brightest

As part of a preliminary study we conducted for the National Academy, I had the opportunity to examine data on the trends of career preferences for our country's very brightest freshmen students. These students were selected by the requirement of a) A/A + high school average, b) their acceptance to every college where they applied, c) their assertion that they intended to go to graduate school and d) that they expected to enroll in honors undergraduate programs. These students were asked to indicate their intended major. Data for the period 1967 to 1983 show that the number specifying an interest in the physical sciences has dropped continuously from 21.3% in 1967 to 7.1% in 1983. This drop corresponds roughly to the increases reflected in the engineering disciplines, while the trends in the biological sciences are rather stable.

This should be a source of concern. While one might argue that market forces explain why more and more students are opting for careers in engineering, it is not in the long term best interests of engineering or the country that there be a significant depletion in the physical sciences of the best students. As argued above, the major developments in physics fuel engineering and technology for decades to come. This is another topic that should be examined, and if remedial steps can be identified, they should be taken.

Activities at the National Science Foundation

Since the report we issued was commissioned by, and primarily responsive to, the role of the National Science Foundation, I would like to review some of the actions that have been taken over the past year.

- The office of Undergraduate Science, Engineering, and Mathematics Education was established within the Directorate for Science and Engineering Education. This office will have the responsibility for "coor-

dinating the NSF mission in undergraduate education across the Foundation," managing the undergraduate activities budgeted within the Science and Engineering Education Directorate, and stimulating the improvement of undergraduate science and engineering education.

- The Research Experience for Undergraduate Program was expanded. This program is designed to "attract talented students into research careers in the scientific fields, and to help insure that they receive the best upperdivision undergraduate education possible." As many of you are aware, this program has two components: one provides "Site" awards and the other provides "supplements" to existing NSF research grants. For FY1987 the Foundation made 143 site awards for $5.2 million and 835 supplements for a total of $6.7 million. The Foundation estimates that 2800 students were supported through this program should have a high priority within the Foundation, and I am quite pleased to see that it is off to a good start.

Concluding Remarks

I am very pleased to note the interest of the APS/AAPT Physics Chairs in the quality of the undergraduate education we are providing to our students. Chairs, who are uniquely positioned by virtue of having responsibility within their departments for sustaining both research excellence and teaching excellence, can provide effective leadership for their faculties by stressing the unity of the two missions, rather than the confrontational aspects we so often hear. Teaching and learning of science should be a rewarding experience for both the faculty and student. When that ceases to be the case, there is a problem. But, just as we collectively attack and remove obstacles that prevent us from achieving our research objectives, we can accomplish the same result in our instructional efforts if we accord them the appropriate priority.

*Graduate Education and Research in the Era of Large Accelerators**

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I. Issues and Questions

In the past three decades, the great progress in elementary particle physics and its associated technologies – accelerators and detectors – has brought changes in research methods and research style.[1, 2, 3] Most experimental work in particle physics involves: huge accelerators; large and complex particle detectors (Fig. 1); collaborations of many physicists; and long times for equipment building, data acquisition, and data analysis.[3, 4, 5]

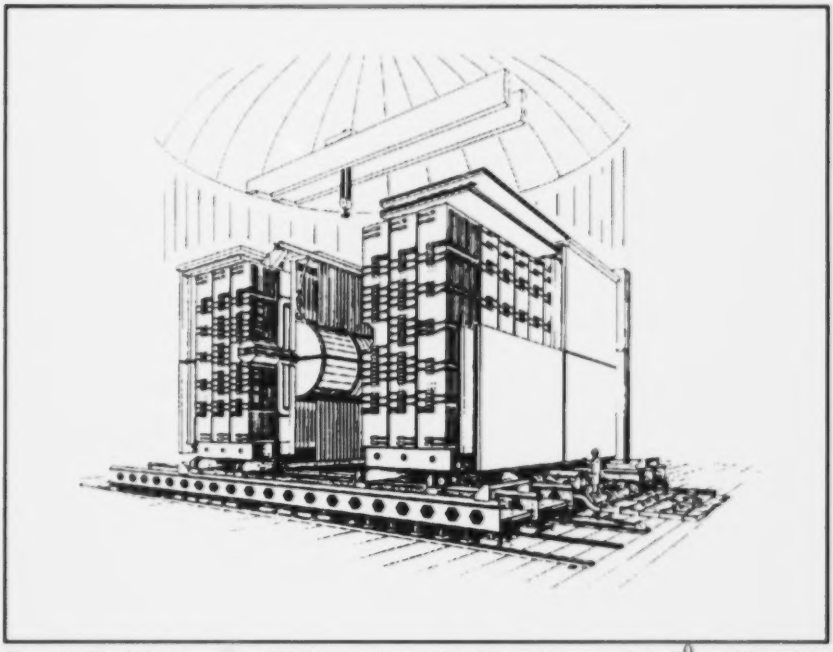

Figure 1. The UA1 detector at CERN used for the Nobel Prize discovery of the Z^0 and W particles that carry the weak force. Note the large size of the detector compared to the person standing at its lower right side.

* This work was supported by the Department of Energy, contract DE-AC03-76SF00515.

These aspects of experimental particle physics have raised questions in the physics community as to how to evaluate the quality and contributions of the research of individual experimenters: graduate students, staff, and faculty.[6, 7, 8]

The questions and concerns of the community fall into five categories:

Quality: Is the quality of experimental particle research per individual as high as other areas of physics?

Independence: How much independence is there in this research?

Creativity: Can most physicists be creative in this research work?

Evaluation and Recognition: How can the contributions of individual students, staff, and faculty be evaluated and recognized?

Value in Graduate Education: What is the educational value of having experimental particle research in a physics graduate program?

My discussion is based on three kinds of information. First, I consider a case history: the present Mark II collaboration at the SLAC Linear Collider (SLC), of which I am a member. Second, I rely on my observations during 30 years of particle research at the University of Michigan and at the Stanford Linear Accelerator Center. Third, I use the literature in the references.

There are several major limitations to my discussion. It is restricted to the physics community in the United States. The discussion does not include research in particle physics theory or in accelerator physics and technology. The increasing importance of the latter field deserves a separate discussion. I will not discuss the basic question of the proper balance between large scale and small scale physics research with the concomitant issues of funding, priorities, and visibility.

Another basic question which I will not discuss is the philosophical one raised particularly by Pickering.[8,9] Is the study of leptons and quarks the only possible form of elementary particle physics or is there a different direction that would not be so demanding of large accelerators and equipment? I take experimental elementary particle physics as it is practiced today, worldwide. I examine the effects of that practice on the education, careers, and research of the individual physicist.

II. The United States Particle Physics Community

As a framework for this discussion I give an overview of the numbers of physicists, of the number of groups, and of federal funding. Table 1 gives the number of U.S. physicists in a 1981–1982 survey, the numbers have not changed much since then.[10]

At present the U.S. National Science Foundation (NSF) supports about 60 grants in experimental particle physics at about 40 universities.[11] The Foundation also supports the CESR electron-positron collider facility at Cornell University.

The U.S. Department of Energy (DOE) supports about 110 tasks in experimental particle physics at about 60 universities and at the Lawrence Berkeley Laboratory (LBL) and the Argonne National Laboratory (ANL).[12] The Department of Energy also supports the three large high-energy accelerator facilities at

the Brookhaven National Laboratory (BNL), the Fermi National Accelerator Laboratory (FNAL), and the Stanford Linear Accelerator Center (SLAC).

The federal funding in fiscal year 1987 for elementary particle physics is given in Table 2. Operating and equipment funds tend to change slowly from year to year, but construction funds vary depending on what is being built that year.

The four accelerator facilities provide particle accelerators and colliders for the use of physicists funded by NSF and DOE as well as physicists from outside the United States. Conversely some physicists funded by NSF and DOE use accelerators and colliders in Western Europe and Japan. A few have used accelerators in the Soviet Union.

At present extensive information on the United States particle physics community is being gathered by a subpanel of the High Energy Physics Advisory Panel (HEPAP) to the Department of Energy. The subpanel is chaired by S. Treiman of Princeton University.

III. The Mark II Collaboration at The SLAC Linear Collider

A. The Collaboration

The present Mark II collaboration is typical of associations of experimenters who gather together to build and carry out large experiments at high-energy particle colliders. With 133 physicists it is of average size for such a collaboration: some

Table 1. Number of U.S. particle physicists in 1981-1982 survey from Ref. 10. The numbers are rounded off to nearest 10.

Type of physicist	Experimenters	Theorists	Total
Graduate students with 3 or more years of completed graduate study	450	310	760
Ph.D. level physicists in universities	800	630	1430
Ph.D. level physicists in laboratories	530	110	640
Total	1780	1050	2830

Table 2. Federal funding for elementary particle physics in fiscal year 1987 in millions of dollars. The numbers are rounded off to the nearest million dollars.

Agency	Institutions	Operating and Equipment	Construction
NSF	Universities	23	
NSF	CESR	8	11
DOE	Universities	80	
DOE	BNL	62	10
DOE	FNAL	156	16
DOE	SLAC	106	5
DOE	LBL and ANL	27	
DOE	SSC R&D	20	
DOE	Other	18	
Total		500	42

present and projected collaborations are larger with 200 to 400 physicists, other collaborations are smaller.

The collaboration began to form in 1983 to carry out three intimately connected physics studies:

(i) The production physics of the Z^0 elementary particle through electron-positron annihilation,

$$e^- + e^+ \rightarrow Z^0$$

will be studied. The Z^0 which along with the $W^{\pm}$ carries the weak interaction, is the heaviest known elementary particle – 92 GeV/c^2.

(ii) The properties of the Z^0 will be measured.

(iii) The decay processes of the Z^0 into many different kinds of particles will be studied to measure the properties of known particles, to search for new particles, and to search for new interactions.

Table 3 gives the composition of the collaboration: seven groups from universities and five groups from the LBL and SLAC national laboratories. This collaboration has a larger-than-average fraction of national laboratory members because of its history. The category Ph.D. staff excludes faculty but includes

Table 3. The Mark II Collaboration as of February, 1988

Institution	Graduate	Ph.D. Staff students	Faculty	Total
Cal. Tech.	3	5	3	11
U. of Colorado	2	1	2	5
U. of Hawaii	1	2	2	5
Indiana U.	3	2	3	8
Johns Hopkins	2	3	2	7
LBL	2	10	2	14
U. of Michigan	3	3	2	8
U.C. Santa Cruz	5	9	4	18
SLAC Group A	0	1	2	3
SLAC Group C	8	12	2	22
SLAC Group E	4	9	3	16
SLAC Group H	3	10	3	16
Total	36	67	30	133

postdoctoral research associates and visitors. To see what these 133 physicists have done and are doing, I turn to the apparatus, Fig. 2.

B. The Apparatus

A modern, multipurpose, experimental apparatus at an accelerator or collider has three components:

(i) Particle Detectors: The part of the apparatus one sees directly, Figs. 1, and 2, consists of interconnected particle detectors: drift chambers, magnets, electromagnetic shower detectors, muon detectors, and so forth.

This part is huge by ordinary physics apparatus standards, occupying 100 to 1000 m^3 of space and weighing thousands of tons.[4]

(ii) Electronics: Not so obvious is the electronics that includes signal manipulation, data acquisition, data storage on tape or disc, and on-line monitoring of the apparatus performance. The number of channels of initial signals may number 100,000 or more.

(iii) Computer Codes: Large and complex computer codes are necessary for on-line and off-line use. These codes are needed to analyze the data and to monitor the performance of the particle detectors and electronics.

Those such as myself who did our doctoral research 30 years ago may tend to include only (i) particle detectors in our mental picture of the experiment, and we may be careless about (ii) electronics and (iii) computer codes. That is a very wrong picture. The electronics and computer codes associated with a modern particle experiment involve as much inventiveness, ingenuity, technical skill, and effort as is involved in the particle detectors; all three components are necessary.

In the Mark II collaboration, as in most collaborations, individual parts of the apparatus are designed, built, maintained, and improved by a few physicists working together, usually less than ten, sometimes just one. I call this a working group to distinguish it from the institutional groups. As you will see next, a working group may or may not coincide with an institutional group.

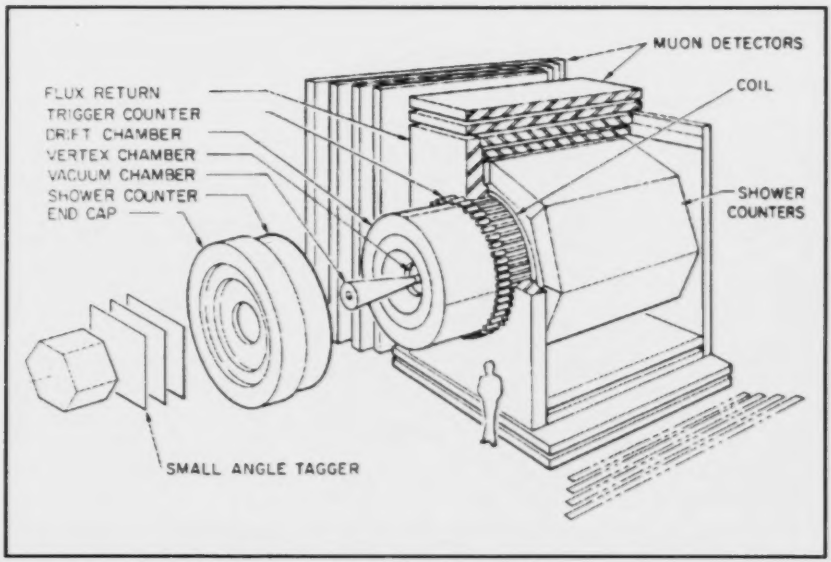

Figure 2. The rebuilt Mark II detector at the SLAC Linear Collider.

The Mark II apparatus is a major rebuilding of an older detector. I list next the individual parts of the apparatus and the institutional groups from where the working group members came. Usually the working group began with the initial design involving new ideas which had to be laboratory-tested, prototypes, and learning new skills. The working group is now responsible for maintaining the apparatus and improving it if time and funds allow. An approximate list of most of the individual parts follows with the associated institutional groups listed in alphabetical order. There is no order of importance in this list. Only the principal involvements of each institutional group are given.

Main drift chamber: U. C. Santa Cruz, SLAC Group E, SLAC Group H.

Inner drift chamber: U. of Colorado, LBL, SLAC Group E.

Silicon strip vertex detector: U. of Hawaii, Johns Hopkins, LBL, U. C. Santa Cruz, SLAC Group C.

Collider background control systems: Johns Hopkins, SLAC Group A, SLAC Group C, SLAC Group E.

Scintillation counters: Cal. Tech.

Data acquisition electronics: SLAC Group C, SLAC Group E, SLAC Group H.

On-line computers: SLAC Group C, SLAC Group E, SLAC Group H.

Data format computer codes: SLAC Group C.

Apparatus simulation codes: SLAC Group C, SLAC Group E.

Small angle particle detectors: Johns Hopkins, U. of Michigan.

End electromagnetic shower detectors: LBL.

Refurbished cylindrical electromagnetic shower detectors: Cal. Tech.

Refurbished muon detectors: Cal. Tech., Indiana U., U. of Michigan.

Magnet: SLAC Group C.

The working groups are voluntary associations. Individuals gather around a part because the technology interests them or because the part is important to their physics interest. For example, the working groups associated with the inner drift chamber and the silicon strip vertex detector are interested in particle decays at small distances. Sometimes a graduate student is in the same working group as her or his advisor, sometimes she or he goes off on their own to a different group. The latter is an example of the freedom that can be provided in a large collaboration.

At the beginning of this section I listed the three components of an apparatus: particle detectors, electronics, and computer codes. Each individual in a working group is usually involved in at least two of these components. Sometimes the involvement is sequential, particle detector and electronics construction coming first, then computer code writing and testing. There is danger in this sequence; several large experiments have had poor initial performance because the computer codes were rudimentary or incomplete. In the MARK II collaboration a special effort is

made to insure that graduate students and postdoctoral research associates are involved in at least two components.

Up to 20 years ago, most particle physics experiments, except large bubble chamber collaborators, involved 5 or 10, sometimes up to 15 physicists. These are the number of physicists involved in a working group in the Mark II. And the amount of innovation, prototype work, design, and construction carried out by a working group is of the same magnitude as that required for a single particle physics experiment of 20 or 30 years.

C. Physics Results

The SLAC Linear Collider is scheduled to begin producing Z^0 particles through electron-positron interactions in 1988. The Mark II apparatus is in place around the interaction point and the computer codes are ready. There are 20 or more different types of physics results being sought: the Z^0 mass, the shape of the Z^0 resonance, the dynamics of the Z^0 decay into the 5 different known quarks, the dynamics of the Z^0 decay into the 3 different known charged leptons, counting of the number of types of neutrinos, searches for new quarks, searches for new leptons, searches for supersymmetric particles, searches for the proposed Higgs particles, searches for new forces, and so forth.

Graduate students and Ph.D. level researchers are completely free to choose the physics that interests them. Important or fashionable topics will have several physicists, sometimes as much as five or ten. Unfashionable topics, obscure topics, long shots may occupy only a few physicists or just one. For example, I want to examine Z^0 decays into very few particles, looking for new phenomenon. No one else in the collaboration is interested in the methods I use, so I developed them by myself and will apply them to the data by myself. A graduate student is similarly free to work alone analyzing data, but she or he must have the right combination of confidence and foolhardiness.

When a number of physicists are interested in the same topic they may work together or separately. Most physicists like to work with a few others. But there are some who believe that the one who travels alone travels fastest. As in the physics community, inside the Mark II collaboration just about all the credit goes to the one who gets there first – if they are right!

If the experiment works as planned, it will produce more results and more important results than its equivalent of 10 or 20 single purpose experiments. The combined analysis power in the particle detectors, electrons, and computer codes of the Mark II allow one to make discoveries of phenomenon which were not conceived when the apparatus was designed.

This is what happened when my colleague Gary Feldman and I discovered the tau lepton (τ) 13 years ago with the Mark I apparatus at the SPEAR electron-positron collider. We found the unexpected reaction

$$e^- + e^+ \rightarrow e^{\pm} + \mu^{\mp} + \text{missing energy}$$

with no other particles or photons produced. This reaction turned out to come from the intermediate step

$$e^- + e^+ \rightarrow \tau^- + \tau^+$$

The Mark I was the first multipurpose apparatus at a particle collider. With it we could identify e's and μ's, we could show no other particles or photons were produced, and we could show energy was missing. Although the Mark I apparatus was not designed to find the tau lepton, we found it.

IV. An Aside on Small Particle Physics Experiments

This talk is about large particle physics experiments and large collaborations of physicists. I point out that not all particle physics experiments are large. Some accelerator experiments are carried out by half a dozen to half a hundred physicists. These are usually fixed target experiments. The smallest are often neutrino oscillation searches, particle decay studies, or beam dump experiments with relatively simple apparatus and a few parameters to measure.

Non-accelerator, non-reactor particle physics experiments are increasing in number. Examples are searches for dark matter, searches for magnetic monopoles, measurements of very high energy cosmic rays. Sometimes the entire experiment is carried out by a few physicists. On the other hand, some new underground experiments are approaching the large collider experiments in apparatus and collaboration size.

Information on the distribution of experimenters among various kinds and sizes of experiments is being gathered by the HEPAP subpanel mentioned at the end of Sec. II.

V. Some Answers and Some Remaining Problems

At the beginning of the talk I listed five categories of questions and concerns about experimental particle physics: quality of research, independence in research, creativity in research, evaluation and recognition, and value in graduate education. Most of the questions have answers, many positive but some negative; and there are problems remaining. I discuss these answers and problems as they come to mind.

A. Quality of Research

Particle physics uses the full range of experimental physics skills. There are many opportunities for invention and development of new devices, new data analysis methods, and new computational methods. The quality of research will be good if the physicist is good. As in the rest of science, experiments can be wise or foolish, clever or dull, lucky or unlucky. The problem is how to decide what physicists in a large collaboration did fine research resulting in a wise or clever or lucky experiment, Sec. V.D.

B. Independence in Research

There are opportunities for independence in a wisely organized collaboration, even a very large one. Physicists can follow their interests in apparatus development and in particle physics within the scope of the experiment.

But the physicist's independence is limited when she or he wants to change the apparatus or change the experiment's parameters – change the energy for example. Then the collaboration has to be convinced, and if there are several experiments using the same particle collider, other collaborations may have to be convinced. Unfortunately, the ability to convince may depend upon one's status in a collaboration and one's political skills. Of course this is true in all joint research work, but it is less important if an experiment is small and easily changed.

C. Creativity in Research

Paradoxically, large particle physics experiments support and encourage creativity in some people while repressing creativity in other people. Creativity is stimulated in people who like to invent and develop new kinds of apparatus. Here apparatus as defined in Sec. III.B means particle detectors, electronics, and computer codes. There is a large payoff for better apparatus performance at less cost in large experiments. Creativity is also stimulated in people who like to range over all the data acquired by a multipurpose experiment, who like to look for new phenomena, who like to test new ideas.

Creativity is repressed in some people partly by the rigidity of a large experiment, by the need to construct on a schedule, by the need to carry out long and tedious data handling and analysis. But more of the problem comes from the pressure to do what is conventional and fashionable. Some topics are in, some topics are out. Some null results will be quoted by every particle theorist, some beautiful measurement will be ignored by every particle theorist.

The question of where creativity, and also where independence, can thrive comes down to a question of personality. Some people don't mind the pressures of a large collaboration, some are even stimulated by going against the fashionable, by going against the conventional ideas of other collaboration members. Other people need quiet and gentle support for creativity and independence. Good physics and great physics comes from both kinds of people, but the first kind has an easier time doing physics in large collaborations.

D. Evaluation and Recognition for Research Staff and Faculty

The question is how to evaluate the work of a physicist in a collaboration of a hundred or more physicists. The answer has two parts. First, a department has to find out what she or he did and how well they did it. Second, a department has to judge the worth of what was done.

Finding out what was done and how well it was done requires phone calls to, and letters from, collaborators in the same working group or who are knowledgeable about the working group. If a physicist worked on the on-line data acquisition system, what do the other physicists in the collaboration who know about data acquisition say? Did the system work well, did it use modern technology, were there innovations? Is the physicist competent in both electronics and programming? Remember that such a system is as complicated or more complicated than an entire particle physics experiment of 20 or 30 years ago. Thus the same care has to

be applied to evaluating a physicist's contribution to a part of a large particle physics experiment as is used to evaluate a non-particle physicist's contribution to an entire small experiment.

The second part of the answer is concerned with judging the worth of what was done. Here I have a quarrel with the standard of worth often used in experimental particle physics. As I discussed in Ref. 13, there is too much emphasis on the contributions of a physicist to the data analysis, to the final numbers coming out of the experiment, to the Physical Review Letter. But most of the heart and much of the soul of a large particle physics experiment lies elsewhere. They lie in the conceiving and design of the apparatus, in the construction of the apparatus, in the careful collection of data, in efficient use of the accelerator.

Ask the senior members of a collaboration, when they are relaxed and not writing letters of recommendation, about the post-doctoral research associates in the collaboration. They will talk about a research associate who helped build a drift chamber and has the design ability of a mechanical engineer and the steady hands of a watchmaker. They will talk about another who devised a new fast method for finding particle tracks. Those research associates are the treasures. Oh, they will talk about wizards in data analysis, but only about the wizards.

The long time from the conception of a large particle physics experiment to its completion is becoming a problem in the evaluation of physicists beginning their postdoctoral careers. Some particle experiments from conception to first publication of results may require only three or four years, but others will require eight or ten years. In the latter situation how can research associates or non-tenure faculty be evaluated in three or so years? Departments can evaluate what the physicist contributed to the design and construction of the apparatus if the physicist joins the collaboration early. But physicists who join after the completion of construction may not be able to exercise or demonstrate a range of experimental skills. There is no general solution to this time problem, and it is occurring in other fields: space physics and gravitational radiation detection physics are examples.

E. Value in Graduate Education

I left this concern for last because it encompasses many of the other concerns: independence, creativity, and evaluation. Beasley and Jones have described and discussed the issues.[7] Under proper conditions a graduate student can carry out independent research within a large particle physics collaboration. The student can develop a variety of experimental skills and learn much in a fundamental field of physics. The student can have the opportunity to demonstrate ingenuity and creativity.

The proper conditions that must be provided by the faculty advisor and the collaboration are: freedom for a student to choose the apparatus work and physics; latitude for a student to make mistakes; time to explore new ideas and come to one's own conclusions. But one proper condition cannot always be provided: that the student can get all this done in three or four or five years. Construction lags, ac-

celerators shut down, equipment breaks, and some experiments take eight or ten years even if nothing goes wrong.

At SLAC we sometimes solve the time problem by a graduate student working out physics results from a concluding large experiment, then helping with the initial construction of a new large experiment. Another solution is provided when a student joins an ongoing experiment as some of its equipment is being replaced and improved. But sometimes there is no solution to the time problem. There will be stages of very large and long particle physics experiments when the conditions for proper graduate research do not exist. Some students will turn to the small particle physics experiments described in Sec. IV. But the majority will want to do research at the highest energies, and that requires huge accelerators and large experiments.

VI. FINAL REMARKS

High energy and high intensity particle accelerators and particle colliders continue to be the main tools for studying elementary particle physics. The efficient and creative use of these huge facilities requires large experiments and large collaborations of experimenters. Graduate education and research in particle physics are immersed in that world for the foreseeable future. The main goal is to understand more about the physics of elementary particles and basic forces. But another goal is stimulating new ideas and inventions in particle accelerators and experiments, ideas and inventions which may reduce the size and complexity of our present particle physics tools.

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Problems in Physics Education: What the Societies Are Doing; What College and University Physicists Can Do

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Introduction

My assigned task for the 1988 Conference of Chairs was to review what various physics societies (especially the American Association of Physics Teachers, the American Physical Society, and the American Institute of Physics) are doing to address problems in physics education at all levels.[1] Beyond that, I want to review some of the major needs in education and suggest what the academic community, led by department chairs, can do to work with and to work beyond the societies to improve the state of physics education in America.

There has been remarkably effective cooperation among the societies on various physics education projects. Needless to say, every society relies heavily on volunteer effort to augment the work of its paid staff members.

Perspective

It is less than 20 years since the societies (even AAPT) began to engage seriously in educational projects designed to influence the content of physics courses, attract more students, improve the quality of high school physics teaching, add to public understanding of physics, and otherwise beneficially affect physics education. (In the early 1960s, the Commission on College Physics did much good work, but AAPT, APS, AIP, and other societies joined in a serious way only starting around 1970.)

It is interesting to correlate the onset of society education projects with what may be called the Vietnam era. It was a time of social ferment in America, and a time when professional organizations decided to initiate programs that reflected a sense of social responsibility – many, but not all of them, related to education. (For instance, a concern for equity in society for minorities and women is broad, but it has an important educational component.) In APS, the Forum on Physics and Society, the Panel on Public Affairs, the Education Committee, and numerous other committees with social concerns started within a very few years. AAPT became equally or even more active at that time and has become a major force in physics education. Along with all the committees and the projects came a strengthening of full-time staffs in the societies that made it possible to accomplish much beyond the traditional roles in publishing journals and holding meetings. (A nearly full-time Education Officer in APS came only two years ago; however, visiting fellows at AAPT started several years ago; and AIP's Senior Education Fellow dates only from 1987 – so the process is continuing.)

What Do We Need?

Education in America at the pre-college level is in a state of crisis.[2] This is not too strong a term. And what is true of education generally is doubly true of science education (where the problems are not confined to the pre-college level).

What do we need? I believe that we need more physicists, especially more U.S. physicists. We need more non-scientists who know some physics and who have a positive attitude toward science. We need equity in education for boys and girls and for white and black and brown. We need more who choose to teach and we need better teaching in the schools. We need new course content and new teaching strategies. Further, we need more who appreciate the intellectual challenge of industrial work. And we need more international ties.

These needs are challenge enough for all of us and cannot be ignored if physics as a discipline is to prosper. The physics societies do recognize them and are taking some steps toward meeting the needs.

What The Societies Are Doing: Some Examples

By examining responses from seven of AIP's member societies and adding what I knew about projects at AIP itself, I quickly compiled information on more than 40 projects based in other societies, universities, national laboratories, and industry. There must be several hundred projects around the country that included physics education and that reach beyond a single institution or single community. A lot is going on!

One useful way to categorize such projects is by the intended audience – the group to be influenced. Here are some examples.

Elementary School

John Rigden and Sallie Watkins of AIP have initiated a project to introduce physics materials into grades K–5 in a St. Louis school district, with the dual goals of (a) teaching physics at that level, and (b) assessing the effectivemess of the material on girls and minority children in comparison with boys and non-minority children.

High School

John Russell of Southeastern Massachusetts University and Brian Schwartz of APS head a project on Local Alliances. Its purpose is to promote working linkages at a local level between college or university faculties and teachers in nearby schools. This project is sponsored by the joint APS-AAPT College High School Interaction Committee (CHIC).

United States participation in the International Physics Olympiad was initiated by AAPT in 1986 and is continuing with the added sponsorship of a number of other societies and industrial companies. Through this program, the very best high school physics students are selected and trained for an international competition. At the local level all over the country, young people see that intellectual excellence, not just sports excellence, has its rewards.

The Optical Society of America (OSA) has been successful in attracting high school teachers to special programs at its meetings. Following the OSA lead, the American Astronomical Society (AAS) launched an equally successful "astronomer for a day" program, and APS is taking a similar approach.

AAPT's Physics Teaching Resource Agents (PTRA) program is, in effect, a national master-teacher program, in which the most gifted, talented, (and eager) high school teachers improve their own skills and then help to spread new information and techniques to their fellow teachers at the regional level. This program, with nearly 300 teachers enrolled, takes advantage of resources available now, not waiting for longer-term solutions – which are also needed to upgrade high school teacher skills.

AIP and several other societies prepare career literature for middle school and high school students.

Undergraduate

Many departments find that physics clubs for their undergraduates are one of the best tools for attracting and keeping majors. Through AIP's Society of Physics Students (SPS) and its affiliated Sigma Pi Sigma honorary society, these clubs are drawn into a national network. Over 7,000 students are now enrolled.

The visiting scientist programs of AIP and APS bring practicing scientists for meaningful visits of about two days to predominantly undergraduate institutions.

AIP has launched a new physics Academic Software program, under the editorship of John Risley of North Carolina State University. Software is submitted much as a journal article might be submitted and is peer-reviewed by referees. Software judged to be of greatest interest is distribtued under AIP supervision, and software authors (unlike journal authors!) are paid a royalty.

Jack Wilson of AAPT and his University of Maryland colleagues Edward Redish, Charles Misner, and William MacDonald are the principals in another computer endeavor called the Maryland University Project in Physics and Educational Technology (MUPPET). In this ambitious program, the computer is used in imaginative ways that go beyond a programming tool or a tutor.

Not since 1962 had the physics community taken a hard look at the content of the introductory physics course. Now, in a program headed by John Rigden and jointly sponsored by AIP, AAPT, and APS, that is happening again. In a series of NSF-supported conferences, physics educators from around the country are examining questions such as the role of modern physics, the role of the computer, and the role of new insights from research on learning in the introductory course.

We cannot overlook this Conference of Chairs! Its power is in the discussion groups in which chairs from large and small departments exchange ideas and discuss common problems.

Graduate

The APS places graduate students in summer jobs in industry each year through its Industrial Summer Intern Program.

The AIP publishes a book that surveys all physics graduate programs in America and continues to gather, analyze, and publish demographic data on graduate study (looking, for instance, at trends in minority and female enrollment, in the percentage of foreign students and foreign TAs, and in jobs, salaries, and age distributions).

Professional

Many societies bring professional-education opportunities to their members – e.g., the AAPT through workshops at its meetings, and the American Vacuum Society (AVS), the American Association of Physicists in Medicine (AAPM), and the APS through short courses for practitioners.

Also notable are the programs of AAPT and AIP to add visiting fellows on temporary assignment to their offices.

The Public

AIP is a leader in science education for the public, through its TV and radio spots, its work in translating research results for the media, and its science writing prizes.

To give one other example among many, the American Crystallographic Association is active in preparing museum exhibits on crystallography.

Educating the public spills over into educating members of Congress and government officials. Under Robert Park's leadership, the APS Office of Public Affairs, based in Washington, is highly effective in doing this.

What does this quick survey add up to? A demonstration that physicists, and their colleagues in related fields, are deeply concerned about education and are actively involved through their societies in a multitude of vigorous and effective programs designed to address educational programs. This is above and beyond the many programs that exist within individual institutions.

If we look for a center of gravity in these society-based programs, it is at the high school and introductory college level. This is not surprising. It is mostly academic physicists who are involved in these projects. They tend to think that all would be well if only the next level down (the high schools) could be improved. Indeed the needs there are great, and some of the new programs are having an important effect. The needs in elementary school are, if anything, even more important. It is a good sign that college and university faculties are also increasingly looking at ways to improve physics education at their own level.

The Problem of Attitude

What else is needed? First of all, a lot of money. A lot of roll-up-the-sleeves volunteer effort is also needed, and that is what is powering the many projects of which the previous section gave a small sampling.

I suggest that we also need some significant attitude changes. Many readers of these words are, I know, working long hours to improve physics education; I hope that they will excuse me for making such a charge. But consider this. Do not most of us believe that physics is an intrinsically difficult subject, that only the thin top slice of college students (or even of high school students) should study it, or are capable of learning it?

Do we *want* to teach large numbers, including those who have no wish to become physicists? Do we *want* to teach in ways that might inspire our students to consider high school teaching as a career? Do we want to provide a meaningful undergraduate major for people headed toward other careers? Do we feel an obligation to contribute to the education of all of the students in our institution? Or do we perhaps rather enjoy our status as the curators of the deep and mysterious knowledge that is ours alone?

I suggest that the splendid efforts of so many people in their own institutions and through society-based projects will become more effective if we begin to see our subject as one that does not belong only to a physics priesthood, if we commit ourselves to finding the right tools and strategy to bring some meaningful physics to everyone of every age, in and out of school.

References

1. AIP is not usually called a "society" (since it has no individual members other than SPS student members), but for the purpose of this essay, I call it one.
2. One of many reports that reaches this conclusion is *A Nation at Risk: The Imperative for Educational Reform,* by the National Commission on Excellence in Education (Superintendent of Documents, U.S. Government Printing Office, Stock No. 065-000-00177-2, April 1983).

Group A:

Recruitment and Teaching of Women and Minorities in Physics

Chair: Demetrius Venable
Hampton University
Expositor: Elizabeth Ivey
Smith College
Reporter: David Griffiths
Reed College

The session began with a report by Professor Ivey reviewing the statistics on women and minorities in physics at the undergraduate, graduate, and faculty levels. After some improvements in the early seventies, the data now indicate a distressing reversal at all levels.

In the discussion that followed there were two major recurring themes: (1) the need for role models, and (2) the importance of "critical mass" in sustaining participation by women and minorities. Speakers identified a number of Points of Attrition at which large numbers of such students are lost:

1. **Elementary School** (many teachers – themselves fearful of science – fail to provide critical support and encouragement).
2. **High School** (parents, counselors, and peers tend to discourage women and minorities from pursuing physics).
3. **College** (a) Freshman year (many are led to believe that physics is "too hard"; women in particular tend not to have had the sorts of experience – tinkering with cars, for example – that makes physics accessible).
   (b) Junior year (a general perception that physics is dominated by white males discourages others from majoring in the field).
4. **Graduate School** (some participants reported that their women graduates drop out of Ph.D. programs more frequently than men; in many graduate schools women are treated with notorious insensitivity).

Several anecdotes were told, recording continuing problems of overt discrimination at all levels.

What can we as Department Chairs do to alleviate the problem? A number of suggestions were made, among them the following:

1. Actively recruit women and minority faculty members (it was noted that the APS, AAPT, and National Society of Black Physicists maintain rosters that can be used for the purpose).

2. Bring and invite minority and women speakers to the campus (again, the APS and AAPT maintain lists), invite successful graduates back to speak to students.
3. Promote the idea that physics is not just for white males (for example, display posters, calendars, films, etc.., documenting the role of women and minorities in the profession).
4. Encourage students to apply to summer programs specifically targeted for women and minorities (such programs exist at SLAC, Argonne, and many other research facilities).
5. Encourage admissions officers (graduate and undergraduate) to be more flexible in their criteria – looking for promise as well as actual experience.
6. One speaker reported success with a non-rigorous, first-year physics course (designed to make the subject exciting without being intimidating) as a device for attracting women into the field.
7. Get involved in pre-college science education; for example, (a) talking to elementary school classes, (b) assisting in teacher training and support, and (c) approaching school administrators.

These were the suggestions of individuals. The group as a whole proposed the following Resolution:

In an effort to increase the representation of women and minorities in physics, and recognizing the special importance of reaching children at an early age, we urge department chairs to offer tangible support to colleagues who generate and participate in programs to improve science instruction for female and minority students at the elementary and secondary level.

Group B1:

Undergraduate Physics Education: Do We Need a New Curriculum for Graduate School-Bound Majors?

Chair: Rex Adelberger
Guilford College
Expositor: Don Holcomb
Cornell University
Reporter: Jack Bass
Michigan State University

The questions concerning possible curriculum reform defined in the expository paragraph and in the accompanying handout from Don Holcomb appeared to be mainly of interest to larger physics departments. Smaller colleges already seem to do some parts of what is suggested and perceive that they would have difficulty in doing others. They were clearly worried that curriculum reform might be impossible for them to properly implement and could place them at a disadvantage. As examples, it was noted that: only about 1/4 of the class time at many smaller colleges can be allocated to the major, compared to about 1/3 at large colleges; small colleges cannot tailor different introductory courses to majors and non-majors; and major curriculum reform might not be compatible with the different ways in which small colleges have structured their offerings in physics. As a result, the discussion focused mainly on questions raised by people from smaller colleges, concerning: (I) what Graduate Schools require for admission – especially how important are the GREs, what preparation is necessary for their students to succeed in Graduate School, and whether this latter is also what they need to succeed as physicists; and (II) why curriculum reform is needed and what forms it might take. No votes were taken. Following the flow of the discussion, this report is organized mostly in the form of questions, with answers where they were given.

I Grad School Admission

Q1: What do Grad Schools want of BA physicists? – i.e. what do students from small schools have to: (a) *show* to get admitted and (b) *know* to succeed (is there a minimum which must be known, assuming that some additional undergraduate courses could be taken in grad school)?

(a) How important are GREs in admission decisions, and must small colleges teach to the GRE to get their students admitted? It was noted that the curriculum at small colleges often is not well coupled to the GRE. It was also questioned whether the GRE tests for what students need to know. Final-

ly, it was asked whether information was available on foreign vs. domestic scores.

(b) Can more information be provided about what students need to know to succeed than just the names of texts (e.g. Jackson's E&M) that they must be prepared to handle? Is what they need to know to pass courses and exams in grad school also what they need to be professional physicists?

A1: (a) GRE and Admission. Unless GRE scores are unusually low, they seem mostly to be used by Grad Schools as supplementary information concerning students who apply from places for which the admissions committee has no calibration information. Very strong letters from faculty, plus good grades, can often overcome mediocre GREs – at least for the first student admitted from a given small school. Where feasible, letters of reference should compare recommendees to previous students who have succeeded at comparable graduate schools. Students should probably apply to at least 6-8 schools to allow for fluctuations. No information seems to be available explicitly comparing foreign and domestic students.

(b) Necessities to Succeed. No one suggested better information than the ability to handle work at the level of typical graduate texts. It was noted that weaknesses in quantum mechanics and statistical mechanics often hindered success in passing examination hurdles. It was also noted that foreign students are usually the very best from their countries, whereas domestic students are often not the best, except at the very top schools. It is likely that at many graduate schools the foreign students do raise the standards on formal examinations.

II. Curriculum Reform.

Q1: Why is change needed? Is the unhappiness with Content or Product?

A1: Probably both – see Holcomb question list. There is a perception that physics has moved forward rapidly in the past several decades, but that this progress is not reflected early enough in the current curriculum to communicate the excitement of modern physics to majors and potential majors. There is also a feeling that it has been a long time since we re-examined the question of what physicists should know when they graduate at the B.S., M.S., or Ph.D. level.

Q2: If there is reform, can an appropriate curriculum be packaged into a limited number of different courses? Alternatively, is it feasible to cover the crucial topics within a variety of different course structures? If we throw stuff out, where will it go? – certainly not to the high school level. Finally, if we modify the undergraduate curriculum, won't we have to modify the graduate curriculum too?

A2: No answers were given. To answer these questions one would have to reach agreement on the "crucial topics" in the modified curriculum, and

the level to which they must be taught. Probably this cannot be done until a thorough re-examination is nearly complete.

Q3: Should independent research be a required component of the undergraduate major? How important is it that students get a good perception of what research physicists do today?

A3: Everyone who spoke agreed that independent research experience was a good thing, both for learning physics and for understanding what a physicist does.

Q4: What should be the laboratory component of the curriculum?

A4: No specific answer was given, although everyone agreed that laboratory experience was important. It was announced that a Mid-Atlantic Consortium is cooperating to improve Modern Physics (Jr.-Sr. Level) labs by producing modular units, starting with Modern Optics and Numerical Computation. A member of the consortium asked whether $5K for an experiment was too much to expect from small colleges. [An informal poll by the reporter after the session elicited comments from many small schools that $1K/year would be difficult.]

Q5: Should we expand the undergraduate curriculum to five years to cover all we need to cover?

A5: This suggestion did not seem to garner much support.

Some Additional Comments and Remarks

The first course plays an important role when trying to attract new physics majors. Good and interesting teaching performance can be as important as content. Over the past 25 years, a lot of people must have made local innovations in their curricula, but these have not been widely shared. Shouldn't they be? (It was announced that AAPT is examining this issue.) In Grad School, physicists have to learn from journals, not from textbooks. Should we and can we require learning form journals at the undergraduate level?

Group B2:

Undergraduate Physics Education: Do We Need a New Curriculum for Graduate School-Bound Majors?

Chair: Jack M. Wilson
University of Maryland and AAPT
Expositor: Donald F. Holcomb
Cornell University
Reporter: Dorothy Woolum
California State University, Fullerton

Expositor Holcomb discussed a number of provocative questions/issues which he provided to the participants in written form, and these are herewith appended. The Group B topic attracted so many participants that subsequent to an initial joint session with the expositor, the group was divided in two. This is the report from the meeting of one of these groups, designated Group B2.

The Group B2 discussion focused initially on the lower division physics majors curriculum. The key issue raised was that of the desirability of injecting modern physics in the standard introductory course curriculum. This is a question that was instigated by the concern of some that there is a wide disparity between the way physics is done and the way that it is taught. It is also viewed as a revision that might attract more students to the field. Although a few chairs indicated that modern physics is treated in their introductory course, most indicated the contrary, and the discussion centered on the possibilities for and the problems likely to arise in such a revision of the standard introductory course.

Among the potential problems was the consideration that injecting modern physics topics would necessitate the elimination of some topics currently covered in the introductory sequence and that other disciplines serviced by the introductory physics majors course (especially engineering and the other natural sciences) may not feel that such revision is in the best interest of their majors. This is a very significant consideration for the vast majority of physics departments, where the calculus-based introductory course enrollments are dominated by non-physics majors.

Another significant concern was the present lack of appropriate teaching materials. Specifically, it was pointed out that in some cases faculty retraining would be necessary, and in other cases, there were concerns about difficulties in encouraging faculty to offer the new curriculum because of the significant amount of time necessary for new preparations. With respect to the latter, however, it was mentioned that faculty who have made such an investment in curriculum development are already beginning to realize the benefits, particularly in the enhancement of their ability to involve undergraduate students in their research.

Possibilities for such curriculum development that were reported/suggested follow:

1) For physics departments not servicing engineering students, but primarily servicing pre-med students, introductory courses can perhaps afford to treat only the major advances in physics, starting with Newtonian physics and modern physics. Alternatively, some programs might (do) start right off with discussion of the nature of matter and modern physics.

2) For physics departments servicing engineering programs and offering three or four semester introductory sequences, Newtonian physics and special relativity could be followed by modern physics, concluding with electricity and magnetism and thermodynamics. Topics like optics would probably have to be sacrificed and treated in later majors offering.

3) One alternative to a major revision of the standard curriculum, is the possibility of injecting one-unit mini-courses ("dessert" courses) in the lower division curriculum to whet student appetites. Sample course titles included: A Tour of the Solar System, Low Temperature Physics, and Relativity.

In general, the Group B2 chairs favored the exploration of possibilities for injecting contemporary physic in the introductory course sequence and agreed that very significant benefits could possibly result, particularly with respect to the recruitment of majors and the fostering of undergraduate student participation in faculty research. On the other hand, since it was clear that there is a wide diversity of service commitments among phyiscs programs, it was felt that enforcing any kind of uniformity in this was undesirable.

Regarding the upper division curriculum, two major topics dominated the discussion: the computational physics component and the nature of student research involvement. A few physics programs initiate the students to numerical methods and computers in the introductory lecture courses (usually in honors sections). One even accomplishes this in the general non-majors course. Many programs have students using computers for data analysis in lower division labs. Discussion favored consideration of adding a computational physics course, probably at the junior level. However, there were concerns along the lines presented by expositor Holcomb, namely that we just can't keep adding requirements, that we must determine an appropriate synthesis which will require the elimination of some current topics.

Several departments represented require a senior thesis of majors. The vast majority have an optional senior thesis. There was a strong endorsement for involving undergraduate students in research, whether through the vehicle of a formal senior thesis course or not. It is valuable for students to see how physics is done and to allow them the opportunity to do independent work. The group agreed with expositor Holcomb that, if we do not provide students opportunities to develop independence, we are not serving them well.

Finally, the GRE and accreditation considerations generated considerable debate. There was a general consensus that the GRE was of questionable value as to its predictive ability, except for assessing foreign student applicants when there is a lack of other interpretable measures. It was argued that it tends to enforce a uniformity that is not desirable and that it is an inhibiting influence on curriculum development. There were strenuous objections to the use of the GRE as an absolute filter in assessing graduate school applications.

Strong arguments on both sides of the accreditation issue were raised. Primarily, it was argued that accreditation could be used effectively as a lever with administrators to obtain materials, equipment and personnel resources. But it was felt that with accreditation small physics programs would be in danger of losing their major and being reduced to a service program because administrators might feel that they could not afford to achieve accreditation standards. A straw pole showed that the non-accreditation side was favored. Chair Wilson pointed out that a set of guidelines for the evaluation of four-year college physics programs was developed recently and is available from the AAPT. This may prove helpful to chairs doing resource battles.

Group B2 used up its time and its break and was still going strong when it was time to get to the next session. Many topics were left untouched. But the group dispersed with a sense that, while details (particularly with regards to sequencing) varied somewhat among the different programs, on the whole there was basic agreement as to the topics covered in the undergraduate physics curriculum. Furthermore, there appeared general support for maintaining flexibility in individual degree programs. In fact, this flexibility was viewed as a strength of the discipline.

Group B2 – Appendix

Undergraduate Physics Education: Do We Need A New Curriculum For Graduate School-Bound Majors?

Notes by D.F. Holcomb

Some questions to think about:

1. Should we hold to the ideal that there should be a more-or-less common undergraduate physics curriculum for all people bound for professional physics? Or is the growth of the body of physics knowledge so overwhelming that specialization is the only possible response? (The answer to the first question from the "expositor" for this group is an emphatic "Yes." But whether that is the best answer is certainly arguable.)
2. What is the proper role of the modern microcomputer?
   Working it into the upper level laboratories in a sensible way is reasonably straightforward. But what about its use as a numerical calculator in place of and to expand the horizons of analytical work – should computer use be slated into various courses? How can we solve the "startup overhead problem?" Or should there be a "course" in computational physics at the junior or senior level?
3. Does the maturity of the computer mean that we need to rethink the proper syllabi for junior-senior level math courses? (We can't just add the computer and numerical methods on top of the standard expectations for analytical mathematics, without compounding the overload problem.)
4. Do too many of us have a curriculum which is packed with facts, analytical methods, and canned problems at the expense of giving students opportunities to develop independence and to learn "how physics is done?"
5. At what stage should contemporary physics be introduced? Do we intentionally or unintentionally use a principle of "deferred gratification?"
6. Is the effect of the Graduate Record Examination positive or negative?
7. Have we adjusted our relative emphasis in the major curriculum to respond to the changing world of physics within which our students will work?

Examples of Areas which have may have increased in importance:

- Continuum mechanics
- Non-linear systems
- Atomic physics, the second wave
- Links to chemistry (e.g., polymers, liquid crystals, solid state chemistry)

- Fourier transform view of optics

Examples of areas which may have decreased in importance (anyone who tries such a list should put on a suit of armor).

- Lagrangian and Hamiltonian mechanics
- Certain areas of optics
- Analytical solutions of boundary value problems
- A variety of classical electrical and magnetic measurement methods

(The point here is not to argue for this list, but to suggest that such a thoughtful re-examination is appropriate.) Others in the group will undoubtedly wish to add their own questions or answers to this list.

Group C:

Interdepartmental Relationships with Physics: Cooperation, Co-existence or Conflict

Chair: Sallie A. Watkins
American Institute of Physics
Expositor: John T. Park
University of Missouri
Reporter: Reginald A. Ney
Duquesne University

In the normal execution of their duties and responsibilities, department chairs must deal with a wide range of individuals and issues and with the power that is intrinsic to the position itself. How the chair deals with these factors will determine how much conflict he or she will encounter, and, ultimately, will establish how successful the chair will be. One thing, however, is a practical certainty: there will be conflicts which must be resolved. The question then becomes one of: How are these conflicts to be resolved?

In order to answer this question adequately, the department chair must be aware of several factors: what the potential sources of conflict are; how to recognize and identify those situations which may lead to a conflict; and, finally, once the existence of (or the potential for) a conflict has been established, how does the chair deal with the situation?

The sources of conflict that a chair experiences can be broken down into three categories: people, issues, and power. The range of individuals with which the chair must deal varies widely, and may include students who, for example, go directly to the dean with their problems instead of consulting with the faculty member or the chair. The dean then perceives that the chair is unresponsive to students' problems, and a conflict arises.

The members of the faculty within the chair's department, or, for that matter, outside of the department, could be another source of conflict. There are always, in any assembly of individuals, those who are never satisfied with anything and always complain regardless of how good or bad the situation is. There are the "prima donnas" who never think of anyone but themselves and for whom nothing but the best is ever quite good enough. Then there are those who sincerely try to help, but for reasons of ineptitude manage to offend everyone with whom they come in contact and actually make the situation worse rather than better. All of these are potential (or real) sources of conflict and must be managed.

Another category of individuals which is a potential source of conflict is the equal or upper level administrator. The chairs of other departments, for example, are

sometimes sources of conflict when they "look after their own" without taking into consideration the effects that their actions may have on others. Deans can frequently cause conflict when they fail to represent their faculty's position to higher level administration, or when they place their own personal goals above those of the college or school which they are supposed to represent.

In addition to people, issues can be sources of conflict. For example, in tending to the needs of the department and its faculty, the actions of the chair may infringe upon the individual desires of the faculty within the department. For example, the teaching of an entry level course may require the attention of a faculty member who would much rather be teaching a graduate course in his research area, or, in fact, would rather be doing only his research , yet "the bills must be paid." "Turf fights" arising between research sub-groups can cause severe conflicts which, if not resolved by the chair, could result in the complete fragmentation of a department, and/or the destruction of a viable program. One final issue must also be recognized as being a guaranteed source of conflict – change. Any time that changes are required, conflict will most certainly arise.

Another source of conflict that may be a factor with which the chair must deal is the power that accompanies the chairmanship. This power, be it real or perceived, arises from several factors. The delegation of responsibility and rendering of decisions is an immediate and very real source of power. The position itself gives the perception of power, although the amount of power actually possessed by the chair may differ greatly from that which is perceived. Finally, the chair may possess a great deal of personal power (which may, in fact, explain how the individual became chair in the first place). All of these can be sources of conflict which the chair must take into consideration.

Knowing the sources of conflict is only part of the battle. A chair must also be able to recognize the telltale signs of the beginnings of conflict. Almost like living things, conflicts grow, and, as a result, there are several stages in the development of a conflict which are readily recognizable.

In the latent stage of conflict development, there will be general, but quiet unrest, characterized by grumbling and a general sense of unhappiness with the situation. The situation is smoldering, but the conditions for ignition have not yet arisen. During the perceived stage of conflict development, the grumblings are no longer quiet, and the unhappiness is developing into overt unrest. In effect, the spark for ignition has been kindled, and smoke is beginning to appear. The situation is not out of hand, but immediate action should be taken to prevent the glowing embers from being fanned into a raging fire.

If appropriate measures are not taken at this point, then the penultimate stage in the growth of the conflict will be achieved and the conlict will become an open one. At this point, the grumblings will have become outright arguments, and the unhappines will become anger. The fire is burning brightly, and a skilled fireman will be required to douse the blaze. Presumably, the chair is astute enough to real-

ize that control must be regained immediately and will take the necessary steps to do so. However, the sometimes ultra-fast pace of events may preclude effective action, at which time the conflict becomes manifest. In this stage, outright war ensues, and the services of a career diplomat will be required to bring an end to the hostilities.

Recognizing that a conflict exists and identifying the stage of development of the conflict presumes that the chair has allowed a conflict to develop. As with most things in life, however, prevention can be more beneficial than effectuation of a cure. This implies that a chair must be able to recognize the potential sources of conflict, and, further, that he or she be able to distinguish between the real sources and those which are only perceived in order to take the appropriate actions. Being realistic in his or her approach to matters, however, can be as important as being on top of things. Thus, the chair must also realize that not all conflicts can be prevented. What then can a chair do to resolve those conflicts which do arise?

In answering this question, the first premise that must be accepted is that "Knowledge is Power!" Knowledge of oneself, one's adversary, the limits that are imposed on the situation, and what tools are available for use can suggest the methods by which any problem can be solved.

To know oneself, it is helpful to at least know what the extremes are. On one extreme are the "nice guy" and the gentleman. The "nice guy" believes that everyone is like himself and that, because this is the case, there will be no conflict. A step up from this is the gentleman who believes that conflicts can arise, but who also believes that everyone is as gentlemanly as he and that everything can be worked out with a simple gentleman's handshake. At the other end of the spectrum are the "hard driver" and the politician. For these two types of individuals, conflict is a fact of life. The "hard driver" is very goal oriented and constantly pushes to achieve the goal, regardless of who or what is in his path. For this individual conflict is inevitable with whomever he comes in contact. For the politician, conflict is necessary for change to occur, and, therefore, it is something to be encouraged.

A physics chair's adversary is frequently another chair and types of individuals that can be encountered here are several. The first is the "spectator" who simply occupies his or her position and watches the world go by. This type of person does not get involved, and, for this reason, is possibly the most difficult to deal with. If a conflict arises with this type of person, then the solution may have to be found by working with a "second-in-command" or with a subgroup within the involved department.

Another type of chair frequently encountered is the "technician." This type of person is usually very neat and orderly. All matters are tended to immediately and what cannot be handled instantly is organized according to levels of importance, or timeliness or both. Because of the orderly nature of this individual, there will rarely be conflicts with him or her. Conflict upsets order and therefore is not acceptable. If conflicts do arise with this type of person, then solutions may be found by

presenting very precisely logical arguments in the form of an exactly specified, prepared agreement.

A third type of department chair is the "jungle fighter." This person wants to be dean and is always looking for "action" that will help achieve his or her desired goal. Conflicts are a way of life for this individual, and one possible way to resolve a conflict with this type is to convince the person that your solution will ultimately help him or her to achieve his or her desired goal.

Another type of chair is the "gamesman." This individual is closely related to the "jungle fighter," but is not as overtly adversarial. The "gamesman's" department is just another pawn to be manipulated for the purpose of gaining the ultimate win. Conflict is all part of the game, and the solution to a conflict with the "gamesman" is similar to that for the "jungle fighter," convince him or her that you can help achieve the win.

Once the relative positions of the adversaries in the conflict are established, then work can begin to resolve the problem. An important factor to be remembered is that the chair cannot let the situation get out of hand. If this occurs, then the chair is not doing his or her job, and is inviting the intervention of the dean or other upper level administrator. Since these administrators usually have enough of their own conflicts to resolve, they do not appreciate having to intervene, and inviting this intervention is also tantamount to inviting one's own demise as chair.

The resolution of conflicts, then, can be achieved in several ways. Know the limits within which the solution can be obtained. Forcing issues beyond the known limits can turn the situation totally around and can allow matters to get out of control. Use persuasion rather than brute force. Persuading the opposition that the proposed solution is viable may resolve the conflict; whereas, trying to force a solution may have the opposite effect. Turn the problem around and invite the cooperation of the adversary. This may alleviate some of the tensions surrounding the situation and will allow everyone to work toward a common goal rather than pull in opposite directions.

Educate the opposition! The conflict may have arisen from a complete misunderstanding of the circumstances or a misconception about the program. Presenting an open and above-board approach to the opposition will encourage them to do the same. An additional benefit of educating the opponent is the external viewpoints that may be provided which can help to generate ideas to strengthen a program.

In any problem situation, there are always at least two sides to the story. However, there are also common points to all sides of the argument which are frequently overlooked. These common points can serve as anchoring posts around which solutions may be constructed.

Finally, in attempting to solve a problem, do not pit one side against the other by making unfair comparisons. This may deepen the conflict rather than resolve it and may draw another party into the fray when that is neither desirable nor neces-

sary. For example, in fighting for an increase in the physics department's budget, do not use the chemistry department's budget as a point of comparison. Do, however, compare the department's budget to other physics departments' in other schools of similar size and circumstances.

As a result of the foregoing considerations, the participants in the discussion group recommend the following to the main assembly of department chairs:

If physics departments are to survive and prosper in these times of "tight" money and efficiency conscious administrations, we, as chairs of these departments, must:

1. Learn to cooperate and to co-exist with other departments and schools.
2. Demonstrate to our non-physics colleagues our willingness and capabilities to overcome our common problems. Similarly, we must make an honest effort to learn and respect their needs and capabilities as they relate to us.
3. Use the knowledge of our common points to establish collaborative efforts that will allow for efficient use of personnel, funds, and other resources.

Group D:

Teaching Effectiveness —Output Measures Local and National

Chair: Phyllis J. Fleming
Wellesley College
Expositor: J. Woods Halley, Jr.
University of Minnesota
Reporter: Robert J. Swenson
Montana State University

A variety of states, institutions, and accrediting agencies are asking, in increasing numbers, for quantitative output measures of teaching effectiveness. "You say you are teaching physics to your majors, PROVE IT!" The proof may require some kind of a quantitative rating scheme based on a standardized exam.

How should the physics community respond? Should the response be local, regional or national? If we don't respond, what are the consequences?

The expositor addressed one dimension of this problem: to what extent can the GRE be used as an indicator for the success of college physics teaching. This work is being carried out at the University of Minnesota under a grant from the Department of Education. Details of the study can be obtained from the expositor.

Several states, including Arkansas, Colorado, Florida, Missouri, New Jersey, Tennessee, and Texas now require, by law, output measures in higher education. Several others, such as Virginia, Minnesota, and Mississippi, are in the process of considering similar laws. The GRE subject matter tests are being used in some cases as the output measuring instrument. Also the U.S. Department of Education is required to prepare an annual report, "The State of Education," which uses GRE results extensively to determine this "state." Thus the question posed by the expositor—"How well is the GRE measuring the output?"

In order to answer this question, a survey of 80 physics departments was made, with 59 responding. The survey determined what textbooks are used in five areas: mechanics, electricity and magnetism, thermodynamics and statistical mechanics, modern physics and quantum mechanics, and "other." The results of the survey are found in Table I.

Table I. Results of Textbook Survey:

Texts used by 10+ percent of students in sample:

Mechanics:

Marion	48%
Symon	20%
Fowles	13%
Kleppner	11%

Electricity and Magnetism:

Griffith	23%
Hecht	19%
Purcell	18%
Reitz	17%
Corson	17%

Thermodynamics and Statistical Mechanics:

Reif	43%
Kittel	37%

"Modern" Physics:

Eisberg	43%
Liboff	27%
Gasiorowicz	20%
Perkins	14%
Saxon	14%

"Other"

Kittel	30%
Horowitz	30%
Mellisinos	25%
Bows	10%

The departments were grouped into four groups as follows:

Table 2. Textbook Survey – Sample 59 Schools (80 polled)

	Top Grad (TG)	Top Undergrad (TUG)	Random Grad (RG)	Random Undergrad (RUG)
# Schools	14	19	13	13
# Majors	575	208	222	78

This set of departments represents 1000 students or about 20% of the physics majors.

The assumption was made that the textbooks used determined the curriculum context. A group of four experts in each of the five subfields indicated in Table I analyzed a GRE Advanced Physics Exam and the curricula determined by appropriate sets of textbooks. They were asked to determine (I) how well the curricula covered the questions on the GRE exam; and (2) how well the GRE exam covers the curricula. The tentative results are given on Table 3, where the numbers represent the estimated overlap between curricula and GRE exams, with 1.00 representing a complete overlap.

Table 3. Summary of Results

	TG	TUG	RG	RUG
El and Mag R1	0.63	0.50	0.58	0.59
El and Mag R2	0.44	0.42	0.42	0.40
Mech. R1	0.79	0.76	0.84	0.84
St. Mech. R1	0.77	0.61	0.82	0.63
St. Mech. R2	0.17	0.15	0.16	0.18
Modern R1	0.82	0.50	0.85	0.47

CONCLUSION: There is a very poor overlap of the GRE exam and the curricular expectations, and the overlap depends on the type of institution.

The group focused its discussion on two topics: (I) a national exit exam; and (2) accreditation. It was decided that it would be appropriate for a national physics organization to consider the exam issue. There appears to be several outcomes of such a study: (a) Do nothing at the national level and let each state or institution solve their own problem. (b) Decide that the GRE exams are good enough for this purpose, in spite of their deficiencies. (c) Work with ETS to modify the GREs or to develop appropriate area exams. The American Chemical Society tried this tack a number of years ago without success. (d) Partly follow the ACS lead and develop our own exam(s). Due to the variety of programs, several types of exams may be necessary. (e) Follow the ACS lead and develop exit exams and accreditation standards ourselves.

A variety of problems were presented. (a) If "we" do not establish our curriculum and output measures, then "they" (ETS, States, Accreditation Boards) may. (b) Any national exam could lead to uniformity. A strength of our undergraduate education is its diversity. This must be protected. (c) There would be a tendency to teach to the exam. We all would want our students to do well, particularly relative to yours! (d) Students' abilities and departmental missions are very different among institutions. This will cause a difficult norming problem. (e) Exams tend to

measure only one dimension of an undergraduate education; namely, ability to solve relatively simple, short problems. Other and perhaps more important dimensions must not be deemphasized or reduced in importance; dimensions such as laboratory skills, originality, creativity, complex problem-solving skills, style, attitude, and so on. These are much more difficult to measure by standardized tests, and in the end may be the most important.

This group was unanimous in recommending to the Departmental Chairs the resolution:

> APS and AAPT should support a joint committee to study the possibility of developing an exit level exam for undergraduate physics majors.

When Group D met with the entire conference the following was recommended as a subsititue resolution and accepted by the entire delegation.

> Resolved that the AAPT Committee on Undergraduate Education be requested to provide to Physics Department Chairs and to the officers of AAPT, APS, and AIP, on or before September 1, 1988, a concise summary of its findings on existing output-measures activities for baccalaureate programs in physics, along with specific recommendations for action or further study.

Group E:

Faculty and Graduate Students in the 1990s— Stockpile One and Import the Other?

Chair: Robert B. Hallock

University of Massachusetts

Expositor: Beverley Fearn Porter

AIP—Education and Employment Statistics Division

Reporter: Doug Fitchen

Cornell University

This packet presents the basic statistical data underlying the status of physics education today and the prospects for the 1990s. The attached figures and tables highlight six major areas of interest: undergraduate education, the status of women and indigenous minorities in physics, the impact of the increasing foreign component in graduate education, the aging of the physics professoriate in universities, and other supply/demand related issues.

Undergraduate Education

The supply of 18-24 year olds will continue to decrease in the 1990s. The physics community will be faced with the challenge of attracting an increasingly larger proportion of students in order to offset the impact of this decline. In this vein, physics will be competing with other disciplines for top students. One option is to tap the supply of women and minorities, people who have in general remained outside the physics sphere.

Status of Women

Traditionally, women's participation in physics at all levels of education has been low. The attached figures indicate that despite recent small gains, women remain underrepresented. For example, the percent of new PhDs awarded to women doubled in the past ten years, yet it still remains below the 10% mark. In fact, much of the recent increase in physics doctorates earned by women can be attributed to foreign nationals. This poses a continuing challenge to educators and the physics community.

Minority Concerns

Physics, along with the other physical sciences and engineering, continues to attract only a small number of minority students. In the past ten years, the percent of new PhDs awarded to blacks has hovered between 2 and 3%. The situation on physics faculties is even bleaker: blacks hold less than 1% of all university positions. Attracting minorities will become a large issue in the 1990s, when minorities will comprise over 30% of the U.S. 18-24 year olds, traditional college-aged students.

Foreign Component

The attached figure "Percent of New PhDs Awarded to Foreign Citizens, 1971-1986" illustrates the increasing proportion of foreign nationals among new physics PhDs. In 1971, 19% of all physics PhDs were awarded to foreign nationals, while in 1986 that figure jumped to 37%. The composition of first-year graduate students indicates that this trend will accelerate. What effect will our increasing dependency on foreign nationals, as well as the inability to attract U.S. students, have on the nation's scientific and technological future?

Aging

In the past ten years, the percentage of assistant professors in universities has continued to drop and it is now the lowest among the natural and physical sciences. Consequently, the median age of the professoriate has increased to over 50. The bulk of the professoriate will be reaching retirement age in the 1990s. Who will fill the vacancies created by retiring faculty members?

Supply-Demand Related Issues

- After a severe drop in the 1970s, PhD production has recovered somewhat due, in large part, to the increase in PhDs awarded to foreign nationals. What impact will the changing composition of physics PhDs have on the supply of doctorates for the U.S. labor market?
- An increasingly larger proportion of PhDs are employed in industry. As the demographics make their impact felt – retirement of tenured faculty and racial/ethnic changes in the undergraduate population – will the universities be able to compete with industry for the best and the brightest?
- Currently, the number of new PhDs produced seems to be in balance with the demand for people with those skills. However, there is already evidence of spot shortages in the supply-demand balance by area of expertise.

Group E: Discussion

Beverly Fearn Porter presented and commented on her excellent set of graphs showing demographic changes in physics. She emphasized three themes: (1) the aging of the physics faculty (with implications for the inevitable, but delayed surge of retirements), (2) the increasing role of foreign graduate students (half of TAs in physics are now foreign students), and (3) the untapped pool of women and minority students (the increases in physics have been small or negligible).

Discussion in the group focused largely on how to increase the pool of U.S. physics students over the long term. Optimists felt that it was essential and worthwhile to develop schemes whereby faculty devote time to this recruiting effort. For instance, the Saturday open house at University of Massachusetts, attended by more than 80% of high school physics teachers from the state, seems to have had a definite effect on the freshman physics enrollments. A tithing or 10% contribution of time by present senior faculty was suggested as an appropriate way that they could repay the profession for their own good fortune. Pessimists, however, felt that the problems could not be solved by altruism, only by stronger economic intervention and that it was not clear that there would be a happy ending to this story for physics and the country.

There was considerable concern about the strong new disincentive to graduate study in physics caused by the new tax law change. Taxation of stipends (and in some cases tuition awards) for fellows and assistants certainly decreases the attractiveness of these positions, just at the time when we want to increase the number of U.S. students going on to graduate study. The group urges that the conference adopt a resolution pointing out this perverse effect and calling for a change.

The immediate and long term consequences of the substantial reliance on foreign graduate students were discussed only briefly. One suggestion was to look at problems encountered and solutions proposed in engineering, since they seem to be a few years ahead of us on this path.

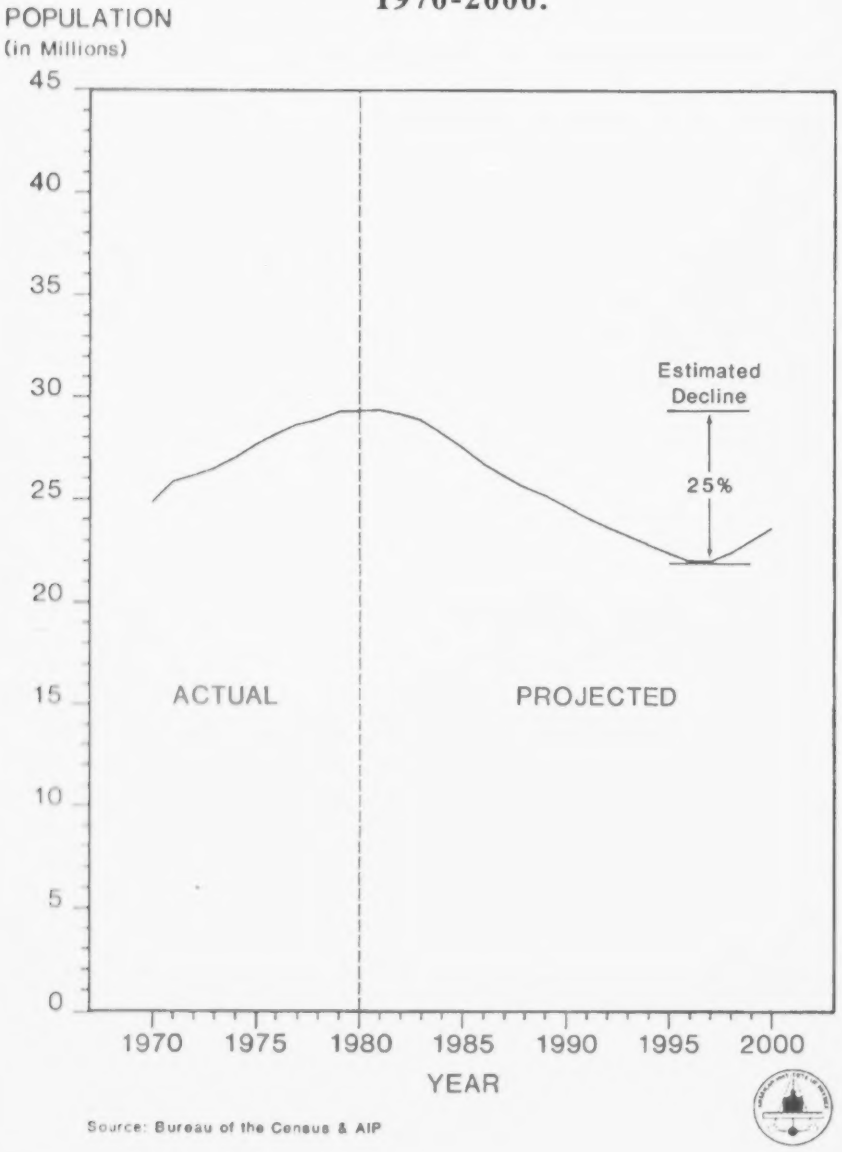
Finally, there was some discussion of circumstantial evidence on faculty retirement behavior as age limits change. Schemes of phased partial retirement (with full fringe benefits), early-retirement bonuses, and part-time appointments were described. One problem noted is that older faculty tend to carry heavier teaching loads, whereas young replacement faculty do not. Should we have an underclass of non-tenured lecturers? Where would we find them?

Resolution

- We urge significant real dollar increases in federal support of basic research programs in physics.
- Physics chairpersons across the nation should become active and effective in the articulation of the plight of physics to members of Congress.
- We adopt as our responsibility the task of motivating faculty involvement in the stimulation of enthusiasm for physics in secondary and elementary schools.

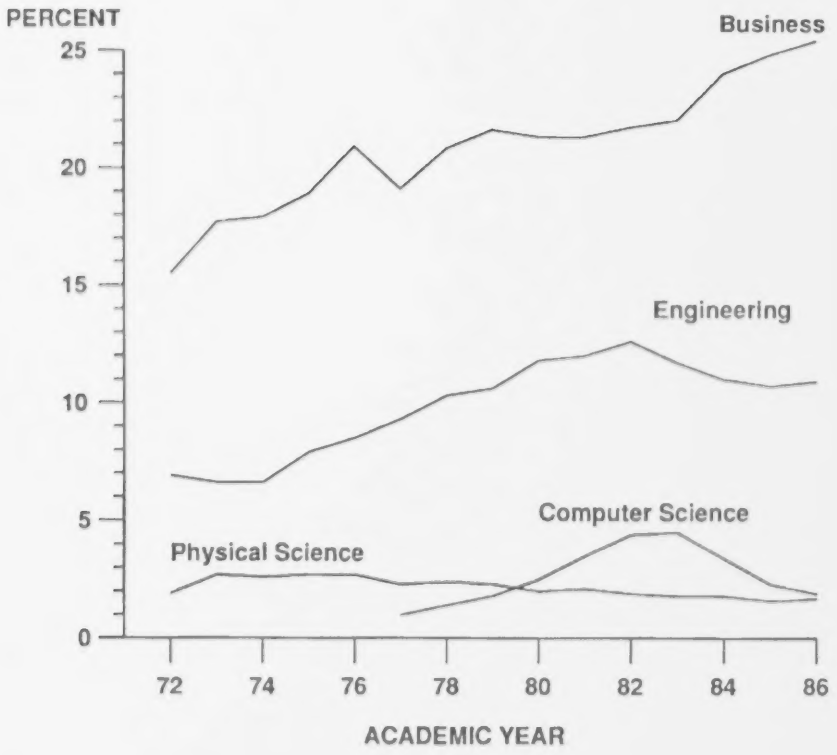
The excellent set of graphs showing demographic changes in physics presented by Beverly Fearn Porter follow.

NUMBER OF 18-24 YEAR OLDS: ACTUAL AND PROJECTED, 1970-2000.



Source: Bureau of the Census & AIP

ANTICIPATED COLLEGE MAJOR of freshmen 1972-1986.



Source: American Council on Education

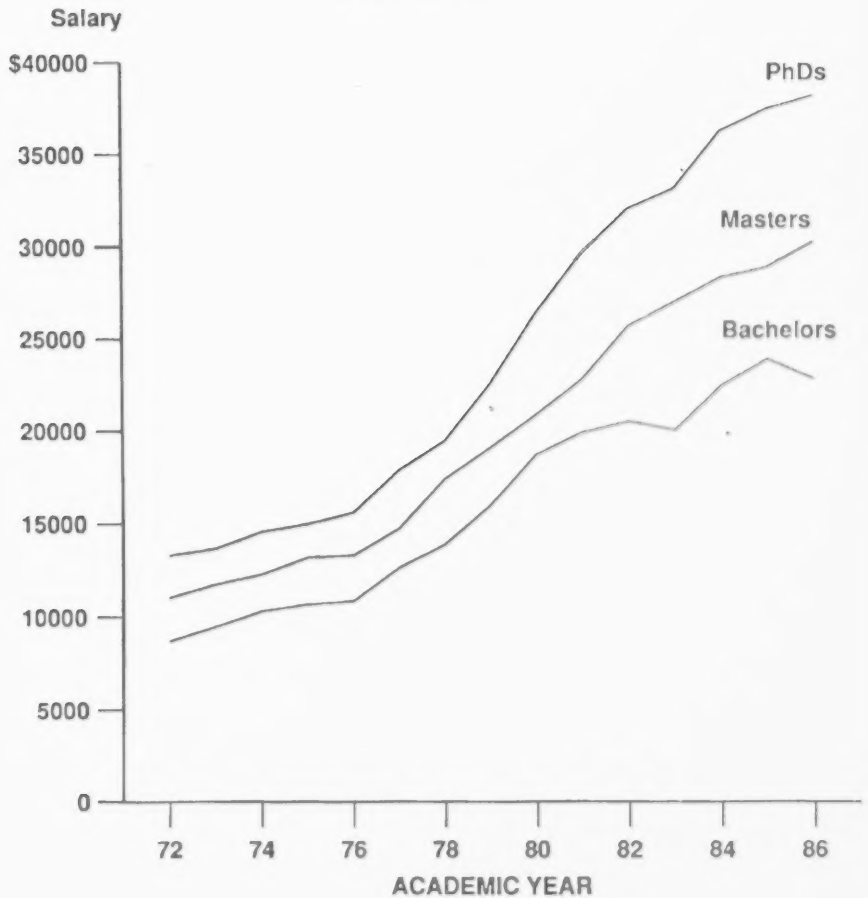
MAJOR SECTORS OF EMPLOYMENT FOR NEW PHYSICS BACHELORS, 1986.

	%
Manufacturing Industry	30
Military	28
Service Industry	18
Civilian Government	13
High School	7
College/University	4

Temporary and summer employment are not included.

Source: AIP, R-211

MEDIAN ANNUAL STARTING SALARY BY HIGHEST PHYSICS DEGREE 1972-1986.



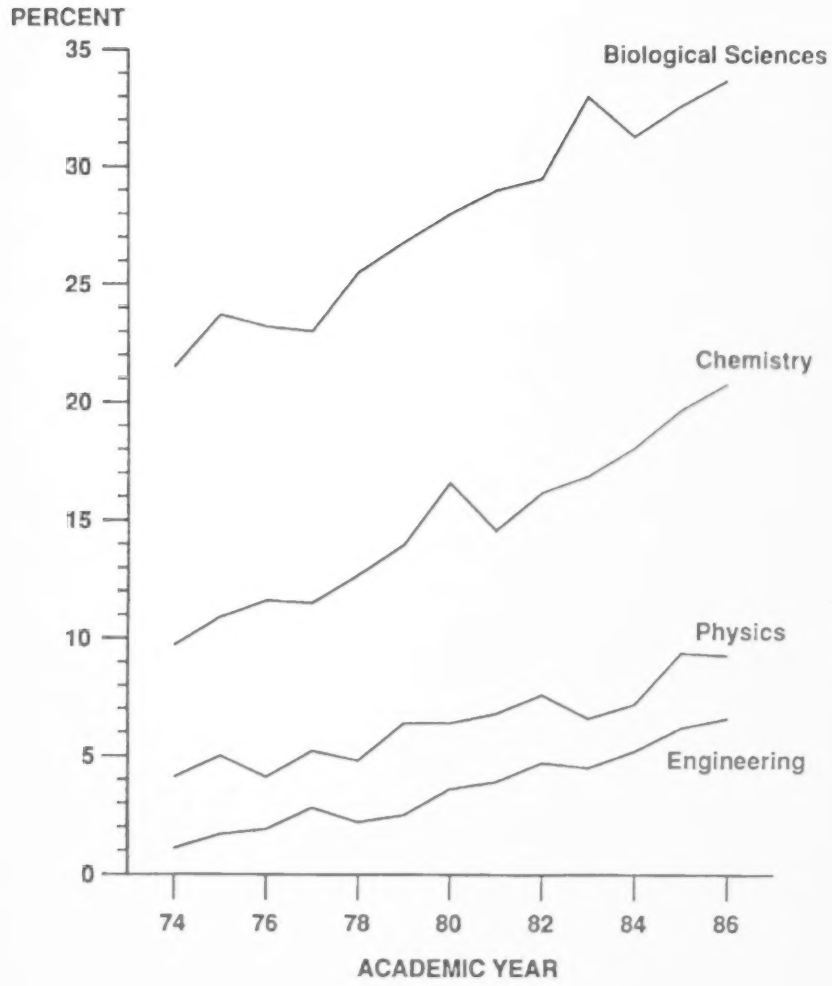
Source: AIP R-207

BACHELORS DEGREES CONFERRED IN PHYSICS BY SEX AND RACE, 1978-86.

Academic Year End	Physics Degrees (Number)	Women (%)	Blacks (%)	Hispanics (%)
1986	5214	13.8	3.7	1.1
85	5188	14.4	2.7	0.8
84	4878	13.7	2.5	0.7
83	4795	11.3	2.4	1.4
82	4558	11.7	2.7	1.0
81	4513	11.2	2.8	0.9
80	4440	9.7	1.8	0.8
79	4416	10.6	2.2	0.7
78	4457	9.3	1.6	0.5

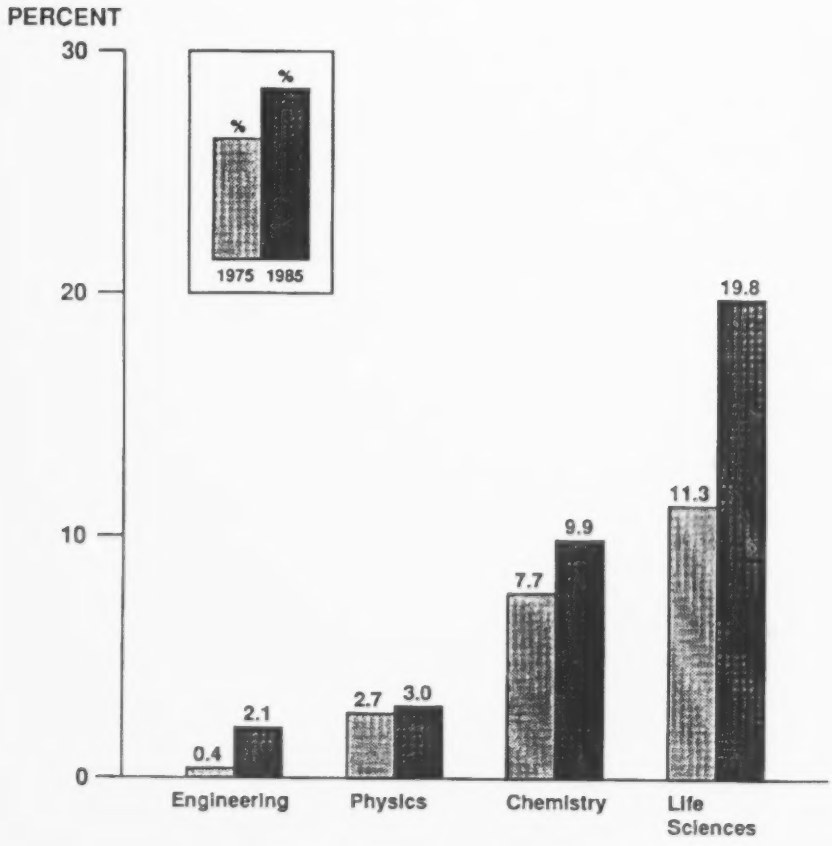
Source: AIP R-211

Percent of PhDs Awarded to Women, 1974 - 1986.



Source: National Research Council

PERCENT WOMEN ON FACULTY IN SELECTED FIELDS, 1975 AND 1985.



Source: NSF

Educational Attainment and U.S. Disadvantaged Minorities

- There has been a serious drop in the rate at which blacks and Hispanics who graduate from high school continue their education.

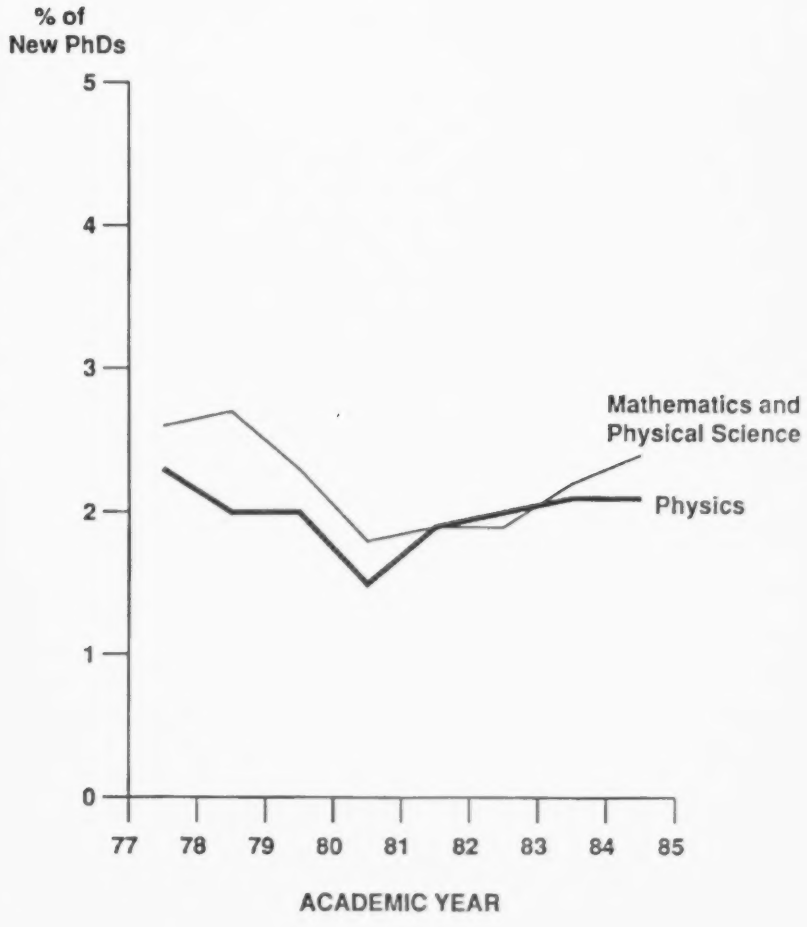
- 77% of white post-secondary school enrollments are in 4-year colleges and universities, while only 57% of black and 58% of Hispanic enrollments are.

- Black enrollments increased from 4.2% of the graduate school population in 1960 to 6.2% in 1978. This small gain has since been lost and blacks now comprise only 4.5% of graduate enrollments.

- During the 1980's the minority population has grown younger and increased at a faster rate, while the majority population has aged and slowed down in growth.

- By 1990, 30% of 18 to 22 year-olds will be Hispanic, Black or Native American.

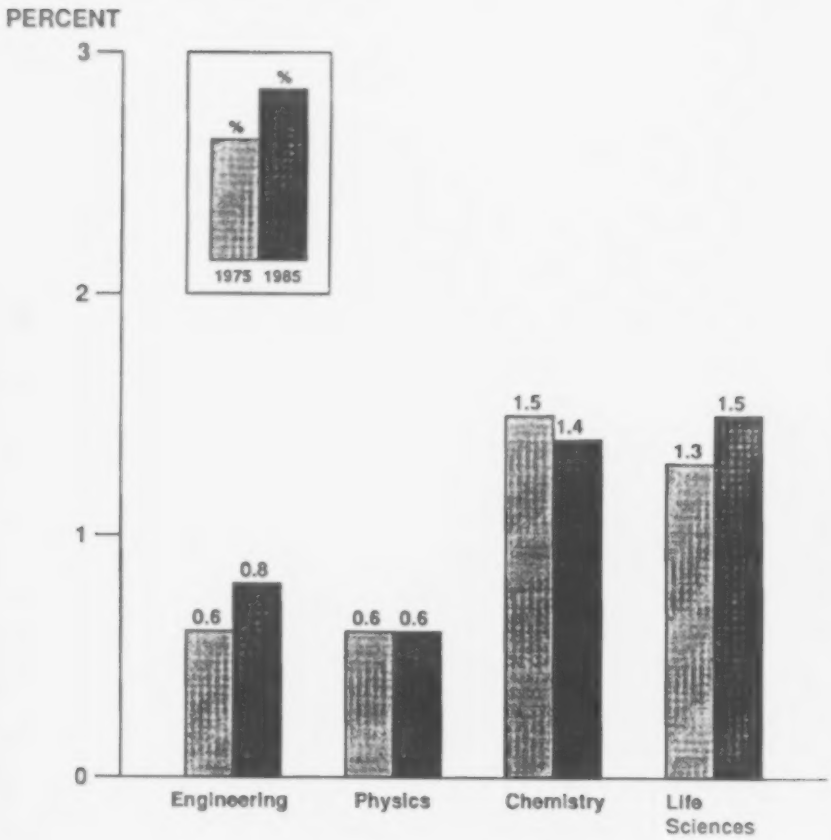
U.S. HISPANICS, BLACKS, AND AMERICAN INDIANS AMONG NEW PHDS, 1977-1985.



Curve smoothed using two-year averages

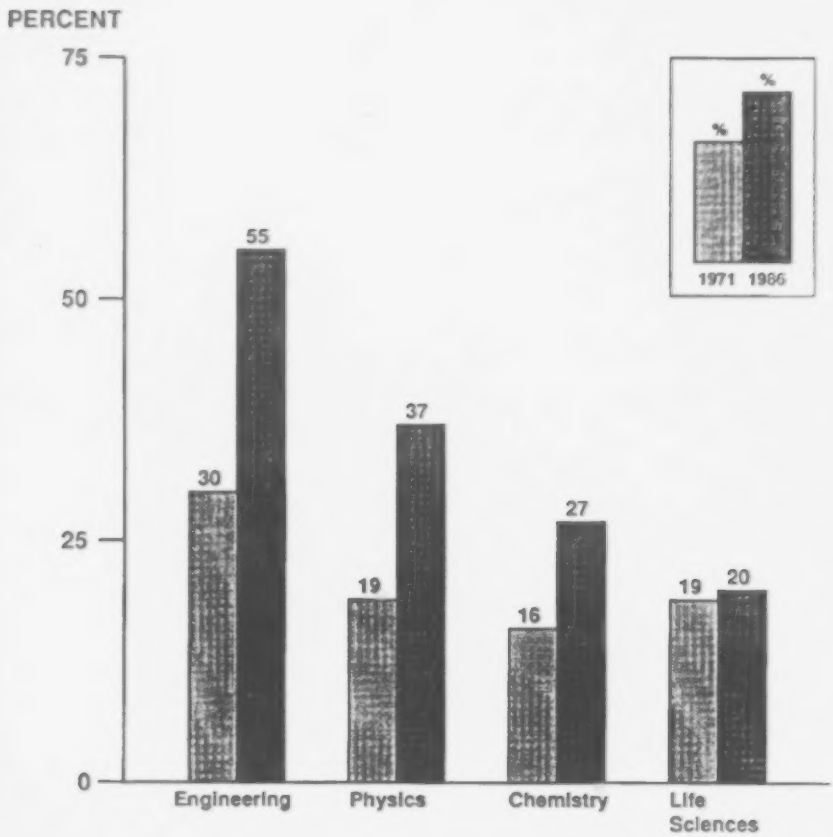
Source: NAS

PERCENT BLACKS ON FACULTY IN SELECTED FIELDS, 1975 AND 1985.



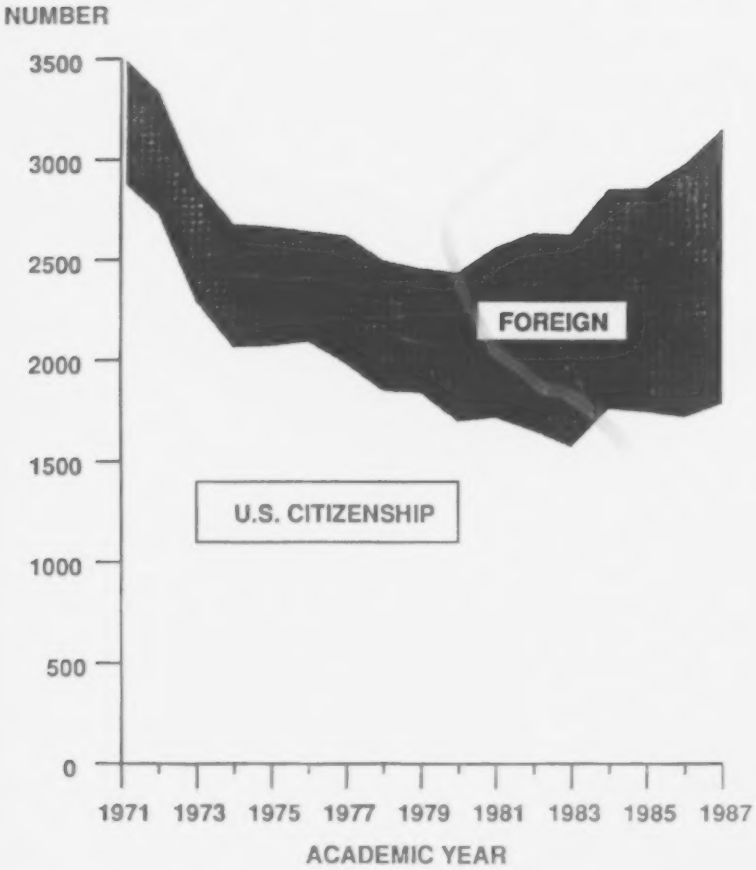
Source: NSF

PERCENT OF NEW PHDS AWARDED TO FOREIGN CITIZENS, 1971 AND 1986.



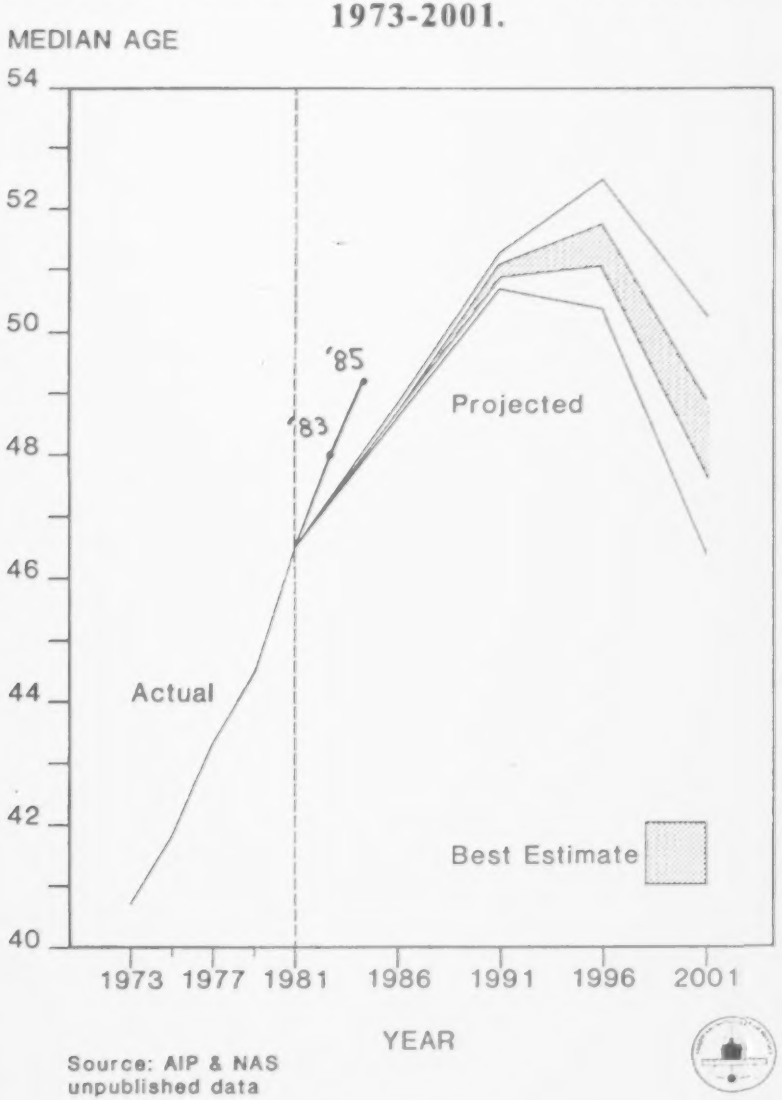
Source: NSF

FIRST YEAR GRADUATE PHYSICS STUDENTS BY CITIZENSHIP, 1971-1987.



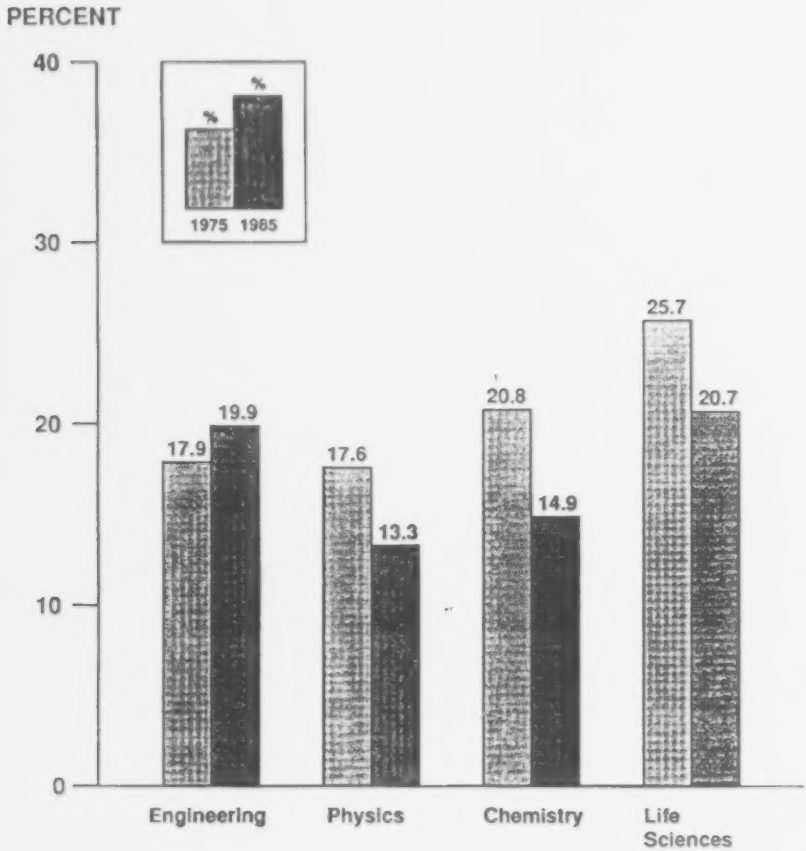
Source: AIP

MEDIAN AGE OF UNIVERSITY PHYSICS PROFESSORIAT: ACTUAL AND PROJECTED, 1973-2001.



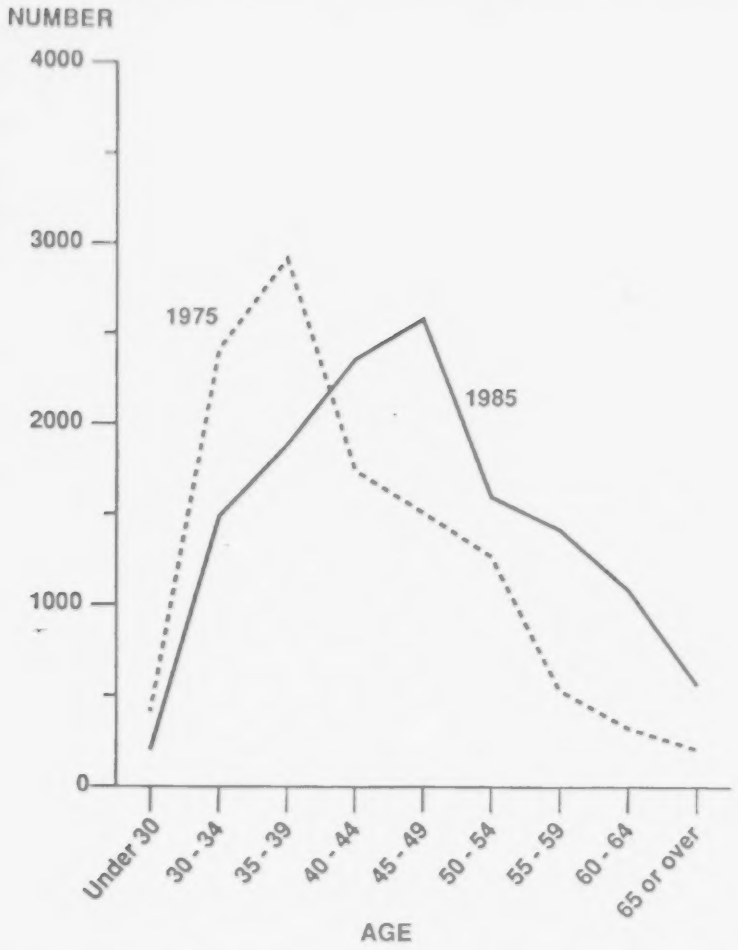
Source: AIP & NAS
unpublished data

PERCENT ASSISTANT PROFESSORS ON FACULTY IN SELECTED FIELDS, 1975 AND 1985.



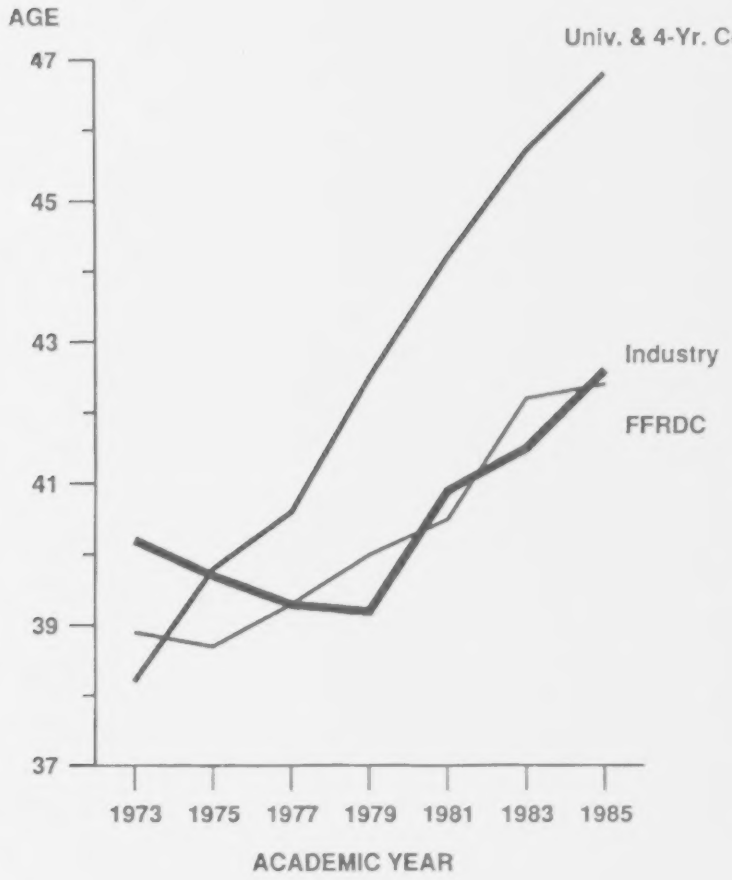
Source: NSF

DOCTORAL PHYSICISTS EMPLOYED IN UNIVERSITIES AND FOUR-YEAR COLLEGES BY AGE, 1975 AND 1985.



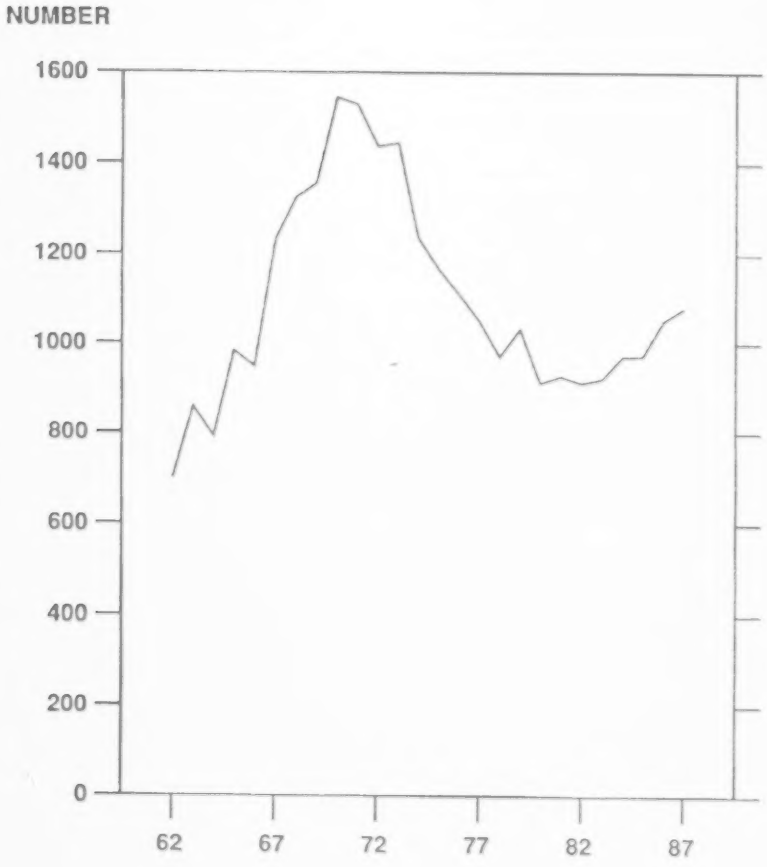
Source: NSF

MEDIAN AGE OF PHYSICS PHDS BY EMPLOYMENT SECTOR



Source: NAS, unpublished data

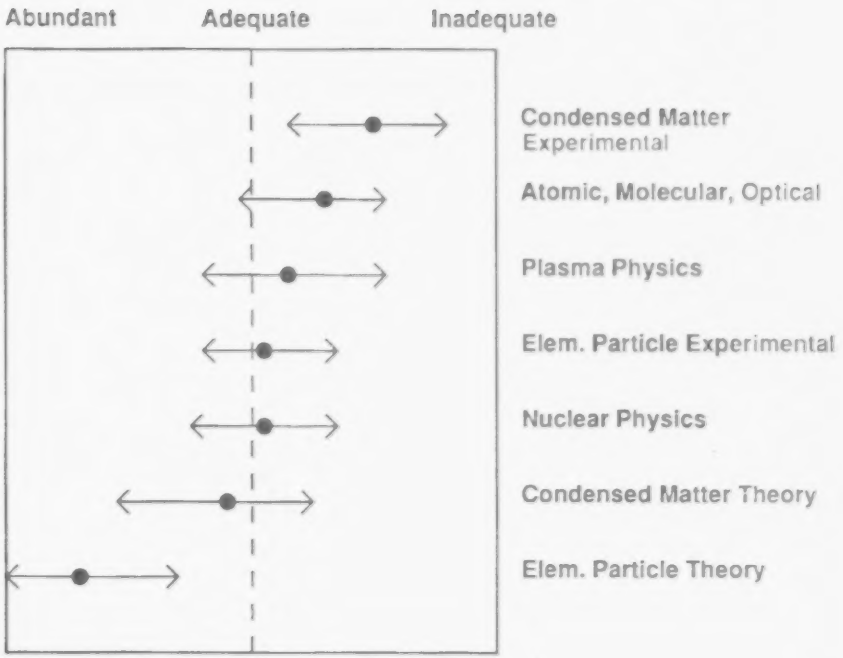
ANNUAL PRODUCTION OF PHYSICS PHDS IN THE U.S., 1962 - 1987.



Source: AIP, R-207

SUPPLY OF CANDIDATES IN SELECTED PHYSICS SUBFIELDS

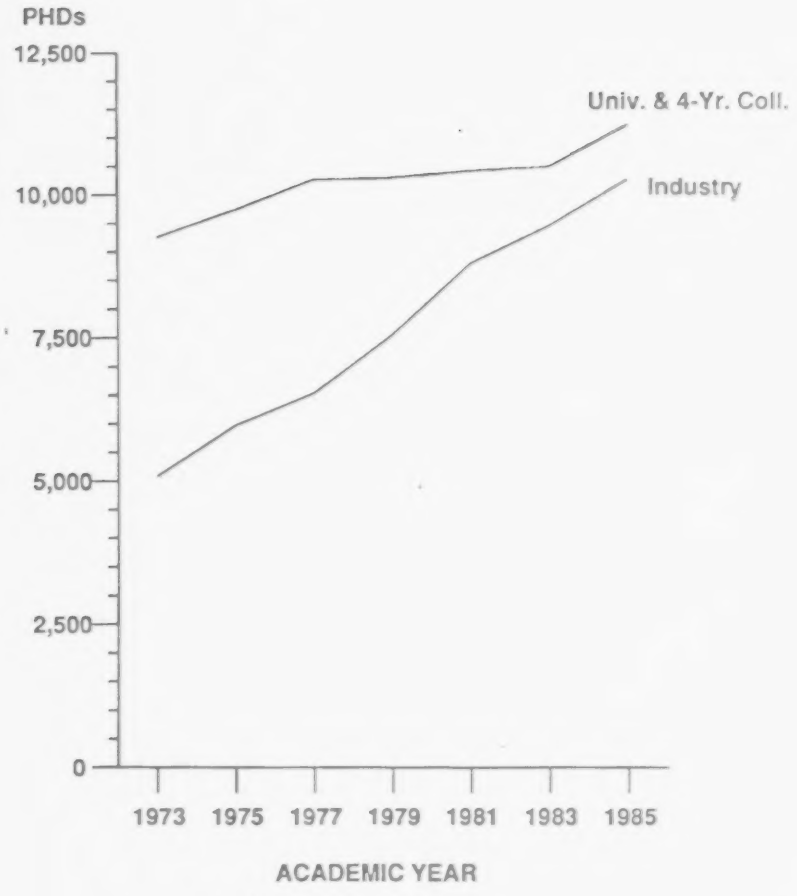
Ratings by University Chairs, 1986



Source: APS, POPA

25th Mdn. 75th

PHYSICS PHDS EMPLOYED IN ACADEME AND PRIVATE INDUSTRY, 1973-1985.



Source: NAS, unpublished data

Group F:

The Decline of the Physics Major— Strategies for Reversal

Chair: James R. Crawford
Southwest Texas State University
Expositor: Robert L. Mieher
Purdue University
Reporter: William L. Gordon
Case Western Reserve University

During his introduction the expositor asked the question, "was the title of this particular session really correct?" He pointed out that the number of baccalaureate physics majors is already increasing. In 1979–1980 there were 4415 produced, whereas in 1984–1985 there were 5214 baccalaureate physics majors produced. However, there are still reasons to address this topic. There is to be a decrease in the 18 year old student pool. In graduate schools there is a decrease in the domestic constituent of the student population. In the mid 1990s there will be the need for additional faculty due to the aging of the present faculty and their reaching retirement age (this problem was addressed by Dale Corson at the previous Topical Conference for Department Chairs in Physics held May 17–18, 1985). Also there are some departments that are experiencing a drop in enrollment and others that would be more vital if their undergraduate majors were more numerous. Thus, the topic of this session seemed appropriate for discussion.

One question that arose in the discussion was, "how many Ph.D. physicists do we need to be producing and how many will we be needing to produce in the future." Most of us remembered the problems encountered in the period around 1970 when there were few positions for the new Ph.D.s just getting out of school. At that time there were some predictions made which indicated that the problem was coming. We feel that some study should be done now to try to predict the number of Ph.D.s needed so that we do not get into a situation where there is a supply and demand problem.

The majority of the discussion in our session centered around ways in which the student pool can be enlarged with qualified students. This list of ideas is by no means complete, but does represent collectively a large number of years of experience in working with physics programs.

1. Work toward more scholarship money for incoming freshman.

- Many students make decisions on which school to attend and even which major to pursue based on financial awards made through scholarships and financial aid.

2. Make available literature which accurately shows the sorts of financial rewards expected for different levels.

- Once again, many students or would-be-students make career decisions based on financial reward. Granted, physics is not as lucrative as some other disciplines, but its financial rewards are respectable.

3. Better quality career literature is needed for those that have contact with students making school and career decisions.

- The opinion of many at the session was that the career literature available from national organizations was inadequate and ineffectual at helping students understand what sorts of things people with baccalaureate, masters, and Ph.D. degrees do with their educations. There is a need for accurate literature that hopefully costs little or nothing.

4. There is a great need for all sorts of outreach programs for the public school systems in a college local area.

    a. Hold symposia for area teachers on your campus telling about what is going on at your campus and what exciting new developments are going on around the world.

    b. Form local alliances with teachers to assist them in any way you or they can think of.

    c. Science days at your university to communicate the excitement and enthusiasm that we all feel (most of the time).

    d. Have your best and most exciting faculty visit the schools for short talks.

    e. It is very important to carry the outreach to the elementary level. These people are often forgotten in favor of the high school physics classes. Elementary children are impressionable.

5. Other ideas besides outreach also were presented. These are listed below:

    a. Consider working toward getting the order of presentation of the sciences reversed so that physics is first (as many in this group felt it should be).

    b. Get the present high school course redesigned so that it is more conceptual and hands-on. Generate enthusiasm for physics.

    c. Consider recruiting students from the two-year colleges. There are a large number of students there that are taking their first year of physics. It is also a good source of minority students.

    d. Exploit dual degree programs (such as 3-2) as a marketing scheme to get students into your physics program.

    e. Seminar on frontiers in physics in parallel with the introductory physics course. This can help convey some of the enthusiasm in physics if presented properly.

f. Provide an interesting pre-introductory course for those not yet into calculus and thus are not ready to start the calculus based introductory course.

g. Modify the introductory calculus-based sequence to include more timely topics than what are currently touched on in that course (the question of content of the introductory course is currently under study by a group with AAPT).

Group G:

Undergraduate Physics Education Curriculum for Non-Graduate Bound Majors

Chair: Richard R. Patty
North Carolina State University
Expositor: Edward W. Thomas
Georgia Institute of Technology
Reporter: Patrick J. Cooney
Millersville University

The expositor opened the session by providing some data on our students who do not go on to study physics at the graduate level. Nationally, some 3500 graduates of our baccalaureate programs per year embark on careers that do not require graduate education in physics. Since this group constitutes two thirds of all our graduating students, they clearly deserve curricula tailored to their needs. Furthermore, since 70% of this group plans to seek employment directly after graduation, these curricula must address the issues of offering these students the skills which potential employers need and seek in entry-level employees. At the same time, these curricula must continue to provide the broad, flexible intellectual base which has traditionally characterized physics graduates. In particular, the 30% of the group who plan to attend graduate school in some other discipline must be offered the basic preparation they need to achieve their goal.

A survey of some 1200 graduates of Georgia Tech's terminal physics programs shows electronics, computers, and optics to be the leading areas in which the graduates surveyed have found employment. There was a general feeling that this employment pattern was probably typical nationally, though no national data on the career paths of our terminal baccalaureate physics majors are presently available. Many participants expressed an interest in such data, both to allow the more informed design of appropriate curricula and to document the value of such programs to potential students. Hope was expressed that the AIP might be able to collect and disseminate such data, though data collected on the career paths of our own individual departments' graduates may be even more valuable for improving our own curricula. Many participants also cited examples of successful individuals in business, medicine, law, government, and other areas who were educated in our undergraduate programs. There was general agreement that we must continue, and even expand, access to the physics major as a general "preparation for life" while also offering curricula which focus on specific preparation for technical employment.

The expositor described a very successful curriculum for terminal majors at Georgia Tech. This curriculum has two identifiable components, the "library shelf"

and the "toolbox." The "library shelf" contains the traditional core of physical theory, including classical mechanics, electromagnetic theory, statistical and thermal physics. The goal of the courses in this category is to provide the student with sufficient background to be able to understand, perhaps with some personal study, new physical principles that she or he will be called upon to incorporate into design and engineering situations. It is important that these courses be complete in themselves and that applications to real problems be stressed. The "toolbox" component of the curriculum represents a variety of technologies that the graduate will need to have at his or her fingertips to apply to the solution of problems. Courses in this second area teach skills in instrumentation, electronics, computer technology, and optics. This component focuses strongly on laboratory experience and should go beyond structured lab experiences to offer the student systems designs experience.

This curriculum philosophy is realized at Georgia Tech in a number of "special tracks" within the physics major program. "Tracks" can be successfully offered in technical areas in which at least one member of your department has expertise but which may not be adequately covered in the standard engineering curriculum. Optics, acoustics, medical imaging, radiology, and electronics-device materials were suggested as possible examples of currently interesting "tracks." The courses supporting such tracks would naturally fall into the "toolbox" curriculum, to be taken during the student's junior and senior years, and should make up about 12% of the total credits required for graduation. There are at least three advantages to offering such clearly identified tracks within the major. Their existence motivates students who are not planning graduate study to seriously consider majoring in physics. Their structure provides a sharp focus for the sustained effort required to successfully complete the major program once initiated. Finally, the skills that they give the student can be particulary attractive to potential employers. It is important for the faculty members proposing a particular track to keep this last point in mind and to document the skills that will aid their students in getting their first job after graduation.

In addition to questions on and discussion of this model curriculum, a number of related issues were raised and briefly discussed. These included the pressing need for many additional, well-prepared high school physics teachers, the importance of physics as a liberal art and the possible inappropriateness of the "specialist track" approach in colleges which stress the traditional ideal of liberal education, the role of research experience for terminal students, the need to encourage industrial recruiters on our campuses to interview physics majors, the courses which may be displaced by offerings in the specialist tracks, the possible impact of such curricula for terminal majors, and the danger of following volatile employment trends too closely in designing new programs. In the end, the consensus of the group was that all physics departments need to be senstitive to the needs of our non-graduate bound majors and to seek ways of better serving them that are adapted to our individual campus settings.

Group H:

The Computer in Graduate and Undergraduate Education— Better Education or Just More Computers?

Chair: Raymond A. Sorenson
Carnegie-Mellon University
Expositor: Priscilla W. Laws
Dickinson College
Reporter: R. Ehrlich
George Mason University

The computer uses in physics can be grouped under three broad overlapping categories: (1) computer assisted instruction (CAI), i.e., tutorials (2) computer usage as a tool for doing physics, whether involving programming or as a data-taking instrument, and finally (3) the computer as an object of study, as in digital electronics courses. Much work is being done around the country in each of these areas at places such as: the University of Maryland, M.I.T., Tufts University, North Carolina State University, Cornell, the U.S. Military Academy, Dartmouth, Virginia Tech, The University of Tennessee, University of California at Irvine, California State University at Hayward, and Dickinson College to name just a few. In some cases the work is being supported by FIPSE grants (The University of Maryland, Tufts University and Dickinson College, for example.) The Dickinson approach involves a complete course: "Workshop Physics" in which computer use and hands-on work with simple equipment entirely replace lecture. Other schools use the computer as simply an adjunct to regular courses. For example, at West Point weekly computer problems are assigned in addition to regular problems. In some cases the computer is used primarily as a data-taking device in lab. However, care must be exerted that experiments do not become "black box" canned exercises in these cases. In many universities, the computer is used in advanced-level "computational physics" or numerical analysis courses, for which several books, including one by Steven Koonin, are now available. Still other universities use the computer as a tutor either using commercial software such as the PLATO system or "home-grown" software. At North Carolina State, for example, an entire course is being conducted via computer tutorials and similarly at Cornell, although students there are given a choice of live tutor or computer, with many opting for the latter.

The economics of computer use remains an important issue, though much depends on how fancy a system one gets. Apparently a lot of money can be saved by buying interfaces and sensors rather than buying complete commercial packages. In some schools each student is required to buy their own computer, although some believe that even if this is financially possible, something may be lost when students do not interact at a common computer cluster site.

some believe that even if this is financially possible, something may be lost when students do not interact at a common computer cluster site.

Clearly computer use will affect course content, and questions remain over what should be taken out in order to make room for computer use. Computer use also poses many other problems such as the tendency of students to be too trusting of the computer as a data taker. The tendency of some students to become "hackers" and forget about physics, the "computer phobia" that afflicts some students (and faculty), the high costs of software development, the tendency for the computer to be the "driver" in student tutorials, and in some other computer uses as well, and the difficulty in selecting the most suitable hardware, software and computer language for a given setting.

The computer languages in most common use continue to be BASIC and FORTRAN (pronounced dead or dying 20 years ago), as well as increasingly Turbo PASCAL, said to be especially good for debugging. In addition, some projects, such as that at the University of Maryland, report good results with students using spreadsheet analysis thereby bypassing the language issue. With regard to hardware, Ataris and Apples are the computers of choice at the lower end of the price range and MacIntosh is the computer of choice for those with more resources and more extensive graphics applications.

Group I:

Undergraduate Research Participants

Chair: Robert E. Warner
University of Notre Dame
Expositor: Jerry P. Gollub
Haverford College
Reporter: Peter A. Beckmann
Bryn Mawr College

The session dealt with a broad range of issues relating to research itself as well as undergraduate research experience. Jerry felt that research and undergraduate education should be seen as mutually beneficial rather than distinct issues competing for time and resources. Students need not be a bothersome aspect of a research program, but rather an integral part of it. Jerry discussed several reasons why it was important for undergraduates to have research experience. First, participatory education is more involving and has a major impact on the individual. Indeed, research experience may influence career objectives for some students. There is little hard data here and there is a need to improve our knowledge of the effects of undergraduate research experience. Second, research participants can favorably effect the local climate for faculty members. It helps in creating a common purpose and can decrease the dichotomy between research and teaching.

Jerry pointed out that a necessary first step was to have strong research programs and this requires, among other things, administrative support. One needs to find the right kind of faculty and one really needs start-up funds in the tens of thousands of dollars range. One must recognize needs for travel and other activities associated with doing research. There was considerable discussion on this point and several participants pointed out that it was very difficult, if not impossible, to conduct a viable research program if teaching responsibilities were at the 10-15 hours/week level. At the same time, several people pointed out that at many of these institutions with a high teaching load, faculty were still expected to publish for promotion and tenure. There was a consensus that this was a very serious problem and ultimately a resolution was proposed. It read:

Resolution from Group I

> Research experience can enrich the scientific development of undergraduates. Heavy teaching loads and lack of research support severely limit such opportunities in many undergraduate institutions. To help physicists at these institutions to gain administrative support for their own and their students' research, we ask APS/AAPT to adopt a forceful statement of the professional responsibilities of academic physicists. This statement should specify an appropriate balance between responsibilities for

classroom teaching and research, and describe other essential support needs of researchers.

At the general meeting the following morning, this motion passed.

Jerry emphasized the potential importance of collaborative research and research that is done off-campus. There tends to be a stigma attached to a researcher if he is not doing research himself on-campus. This stigma is unfortunate and faculty and administrators alike need education in this area. Jerry described some very successful joint faculty-undergraduate research done at national facilities.

One very important issue is that of attracting appropriate faculty. If the appropriate atmosphere involving undergraduate research experience were created, some persons might be wooed from industry and government jobs which they do not really enjoy. Another important aspect in the area of general research is ensuring that faculty are aware of grant oppotunities. The Council of Undergraduate Research has done a superb job in making faculty aware of various opportunities. Their publication is very helpful, write: ***Michael P. Doyle***, Chair and Editor, Council on Undergraduate Research, Department of Chemistry, Trinity University, San Antonio, TX 78284.

Finally, a general change of attitudes is required to create an environment where undergraduate research supervision is seen by departmental chairs, deans, and other senior administrators as an important and normal teaching responsibility.

The next general topic was the process of involving undergraduates in research. Many topics were discussed: Preparation for research, taking account of the differing needs of students, and allowing sufficient time for learning were among them. Jerry suggested that for experimental research with faculty, students did need some laboratory experience beyond the normal first year sequence. The time scale was an important issue and two semesters was suggested as a minimum. Many programs allow students to work in the summer either before or after the academic year. The importance of summer undergraduate research experience was widely acknowledged even by those who were not willing to do it during the academic year. The availability and cost of summer housing was a serious problem in some areas. In terms of teaching effort vs research productivity, sometimes undergraduates prove beneficial and sometimes they do not, independently of the positive experience for the student. With faculty experience, the negative experiences can be guarded against. One exciting and novel consequence of undegraduate research projects is that often unusual and unexpected projects are invented which turn out to be very fruitful.

Jerry felt the presence of a senior person (other than the faculty member) in the lab was very important. This could be a graduate student or it could be a full-time research assistant. RUI grants could request such staffing for institutions that do not have graduate programs.

One very important aspect of involving undergraduate students in research is the benefit associated with the interactions between graduate and undergraduate students. The graduate students learn about the process of teaching in a very natural setting. Some will realize that they enjoy it very much and that it is much more rewarding than they might have previously thought. Also, the graduate students get significant help in getting things done. The undergraduates, in addition to having a very accessible tutor, learn what the graduate student experience is really like. These interactions could have important impacts on career choices and goals. There are potential pitfalls; most importantly, the faculty member must not delegate the supervision of the undergraduate students to graduate students.

There was a discussion about the administrative mechanics of the undergraduate research experience and Jerry suggested that one way was to have it be a course. There was a general discussion about topics for undergraduate research and it was felt that most topics were okay. Some very pure aspects of theoretical physics might require mathematical sophistication beyond the reach of most undergraduates.

There was a discussion of whether or not junior faculty should be involved with undergraduate research. Some persons from institutions with large teaching loads (10-15 hours) felt that junior faculty should not be involved with undergraduate research since it was not very productive and the faculty member would not be appropriately awarded. Again, a general change of attitudes is required to create an environment where undergraduate research supervision is seen by departmental chairs, deans and other senior administrators as an important and normal teaching responsibility.

There was an interesting discussion about whether or not undergraduate research experience plays a role in students determining physics as a major. It was felt that there might be a social factor (seniors talking to freshman about exciting research), but in general this did not play a major role in whether or not a student chose physics as a major.

A very important point was made that there must be a college-wide recognition for the importance of undergraduate research. All agreed that it is unrealistic to expect administrators to single out particular departments for preferential treatment. Jerry felt that administrators could be gradually educated to see the institutional benefits of investing in undergraduate research.

Skirmishes on the Academic-Research Front

Robert K. Adair

Brookhaven National Laboratory

When I accepted Mark McDermott's invitation to speak at this meeting, Mark asked for a title – long before I had any idea as to what I could speak about. So I chose a portmanteau title which would cover almost anything. The title is set, I can't change it. But the strength of my feelings on the subjects I chose to address here are such that, if I could, I might escalate the "skirmish" to "war."

One of the prevailing ideals of higher education is the picture of the student, as an embrionic scholar, sitting attentively at the feet of the teacher, a mature scholar. If the attentive, respectful, student is too often more myth than reality, we do recognize in ourselves – in our aspirations at least – the teacher-scholar.

Of course, there is a perception that some of us, especially at the research universities, may be too much scholar and too little teacher. (That perception can be exaggerated, however. At Yale, the administration collected data on the amount of teaching done by different departments and different areas. To their surprise, they found that the physical science departments – and physics – taught about as many classes and as many students per faculty member as the humanities and more than the social scientists. It appeared that the different sociologies of scientists and humanists at research universities, acted to distort perceptions; the scientists lie about how little they teach; the humanists about how much they teach.) If there may be too much emphasis on scholarship and research, at the expense of teaching, at the research universities, at the colleges some may find it excessively difficult to be as scholarly as they would like. But both scholarship and research – as much else in life – requires resources.

One of the very few advantages I can ascribe to spending so long a time as 40 years as a physicist – working in research, education, and administration – is the personal observation of change. For both scholarship and teaching, we now see a smaller portion of nominally allocated resources than we did four decades ago. The costs assessed to us for the administration of our resources has increased dramatically and continues to increase. The direct charge for overhead costs made to research funds at universities, the less obvious absorption of money for education by an increasing army of college and university administrators, is evident. Is this good? Is this necessary? Perhaps not!

Administration is the operative of organization, and organization is an essential part of human society. Hence, administration and concommitant administrative expense, appear to be as old as civilization – indeed, administration may be a definition of civilization. The 5000 year-old cuneiform writings on clay tablets of the Sumerians of Ur-of-the-Chaldees largely register accounts of the royal (i.e. municipal) stockrooms. The Linear-B scripts from the time of Homer of Nycenae, Pylos, and Crete again, largely record stores and taxes. Even the non-literate Inca's

used records coded in the knots of bundles of colored cords called a quipu to administer a territory that extended for 2000 miles.

The scribe of Ur or Knossos was an administrator, the precurser of the Harvard Business School MA of today. The Inca language Quechua has a word usually translated as "scribe" that was probably used as a label for the administrator who ties the knots of the quipu. From the Sumerian alphabet-syllabary inscribed in clay tablets to the ASCII characters written by computers on magnetic tapes, civilization has rested on its records and the costs of the administration and the records has been a tax on all. Indeed, I rather expect that the origin of writing derived from the necessity of records and that the first literature, the encryption of stories from oral traditions, was very much a by-product of the techniques required for administration.

In Ur or Knossos, at Yale or Brookhaven National Laboratory, or at your own institution, administration is control, and the information gathered and recorded is an instrument of that control. But in the past, fewer records and less control seemed necessary. Maurice Goldhaber, who worked under Rutherford as a young man, told me once how Ernest Rutherford handled research funds and payrolls at Cambridge. He simply put the research moneys he was given into his personal bank account. Then, on the last working day of each month he would go around the laboratory to each scientist and technician to be paid from those funds and write out a personal check for his salary. Rutherford believed in keeping administration in his own hands and he kept costs low. He would say, "Every scientist should spend ten percent of his time at administration. Otherwise it will get into the hands of the bloody professionals."

A little of that efficient insouciance lasted a little longer in odd places. When I first came to Yale nearly 30 years ago, I had occasion to arrange for a refund for some travel expenses and I filled out a simple form and attached my receipts. I was then told – somewhat haughtily – that "Yale faculty are gentlemen and don't lie about money. Hence, receipts are quite unnecessary." When I wanted to buy a house, I borrowed money from Yale as a Yale mortgage (tears come to my eyes when I recall the 4 1/2 % interest rate). I filled out a one-half page form giving little more than my name and the address of the house I wanted to buy. Then a few days later, I got a call from the gentleman in charge who told me that he had driven by the house and it looked fine to him so he had approved the mortgage. Later my colleague Earle Fowler told me that I should consider borrowing from Yale like borrowing from my father.

Needless to say, to gentlemen or to ladies, travel forms at Yale are now as complicated, and as expensive to process, as elsewhere – and returned unprocessed if a comma is out of place. And Father-Yale is now a distant parent indeed and loans no money at any interest rate. Moreover, you can bet that administrative expenses at Yale were low in 1958 and you can be sure that they are much higher now.

Perhaps my favorite story of simple, efficient – and above all, compassionate – administration in the dear departed past, comes from my old friend George Collins who was my boss in my early days at Brookhaven in the 1950s. George told me of getting his pay at Notre Dame in the late 30s. One got in line at the cashier where a Brother of the Order disbursed cash. Once when George was in line, the professor in front of him told the Brother of financial problems as a consequence of his wife's illness and said that he really needed a little more money. The good Brother commiserated with him and gave him an extra two hundred dollars (the better part of a month's salary at Notre Dame in 1939). The money was a gift from the University and not a loan – and with no paper work and only the Brother's scribbled note as a record.

Today, if there are any Brothers of the Order working in the Notre Dame payroll department, we can be sure that they are sitting at computer terminals checking to see that the W-2 forms properly reflect the taxes on fringe benefits.

At any school today, religious or secular, public or private, for travel, payroll, purchasing – or whatever – a long paper trail is now required; at a rule-of-thumb cost of about $50 a transaction.

The level, and the cost, of administrative services have increased as much or more than payroll departments. In 1941, when I joined the 10,000 member student body at the University of Wisconsin, there was just one university police oficer – who seemed to spend most of his time lurking in the bushes to repress student immorality. Now, even though there are no longer immoral students – as a consequence of a change in definition – the University of Wisconsin University Police Force is about the same size as that for the town of Madison in 1941.

How much does this administrative and peripheral service at the institution level cost research and education? A review of the accounting at public universities and the national laboratories suggests that these costs typically run of the order of $25 per $100; for every $100 spent directly on research or education – for salaries, materials, light, heating, building costs, etc., another $25 must be allocated to administration and associated services. The cost is high; more important the proportional cost was lower by a factor of two 25 years ago, has increased sharply since then, and is still increasing.

Here I must pause in my efforts to arraign expansive administrators to admit that I am hardly qualified to throw the first stone. It seems that in my 14 months as an administrator at Brookhaven, I have managed to increase the personnel in my office from 3 1/2 to 4, and increased the office area by an even larger factor. Though the cost of the increment is not great, the whole cost of the office represents a tax of about one dollar for every $100 spent on the high energy and nuclear physics areas under the administration of the office. Is 1% excessive? Perhaps not; but there are very many layers of administration.

It is difficult to question the validity of administrative costs, item by item. Some of the increased cost is necessary to meet increased statuatory requirements con-

cerning taxes, environmental concerns, affirmative action goals, employee safety, human subject welfare, animal welfare, and quality assurance requirements, among others. Some of the costs are for other matters concerned with student welfare, employee welfare, town-gown relations, increasingly complex fringe benefit packages for employees – including you and me – and on and on. Sometimes, as in my office, the expansion seems to be required in order to do better what had previously been done adequately. Is each of these items desirable? Probably. Necessary? Perhaps. Nor is the expense of each particular piece prohibitive. But if the cost of each item is small, there are a very large number of items. I am afraid that we are approaching a kind of infrared catastrophe where all resources will be taken up by the total administrative costs of an almost infinite number of inexpensive peripheral items leaving nothing for our central mission of education and scholarship. I have performed a simple linear extrapolation of trends at Yale which suggest that by the year 2041 there will no longer be funds for faculty or students at Yale – only for administration.

What can we do to control the tides of administration. The trite answer – not wholly false – is not much. But the little we can do can be important. We can demand honest and open accounting designed to display clearly the proportion of institutional resources that go directly to teaching and to research and the portion that goes elsewhere. At Brookhaven that ratio can be determined with moderate accuracy; about two-thirds of the budget goes for direct research costs, one-third for the administration of that research. At Yale, the gold to dross ratio is probably lower but the accounting system mixes gold and dross elements almost inextricably. (I have studied the Yale accounts.) Most colleges and universities, also have accounting systems that do not differentiate clearly between central costs and peripheral costs.

As a kind of technical note, it is often easier to count people than dollars and total costs usually track salaries fairly well.

What can we do then when the costs go too high. We must impress upon everyone that the good things that contribute to the administrative burden displace other good things that are more nearly central to the academy – teaching and scholarship. Primitive peoples at the edge of survival practice triage; sickly infants and the useless aged are set out to perish that the rest can live. We are not so wealthy but that we might have to eject some good things from the academy so that the center can live.

There is another, more narrow, issue of interest to those of us attempting to conduct government supported research, and of special interest to those working at the private research universities. Accounting is an art (maybe even a black art) and not a science. The allocation of administrative and overhead charges among parts of an organization has large subjective elements. About 25 years ago, the private universities began to realize that an astute accountant with a sharp pencil and a devious mind, could arrange to saddle those research portions of the university supported by the government with a disproportionate share of the general overhead

costs of the whole enterprise. The private universities then assigned clever people the sole task of finding arguments that could be used under general accounting rules to justify increases in indirect cost rates to the government auditors. Since neither the university accountants or the government auditors had the foggiest notion as to how the university actually worked, strange and illogical arguments designed to increase the indirect cost charges were proferred and accepted. Consequently, research at most of the private universities became a profit center. (In an uncharacteristic fit of candor, a Yale financial officer once told me that government research was worth $12,000,000 a year to Yale. Since that was some time ago; the number must be $20,000,000 today). In this chase for the government dollar, indirect cost charges to government research at Yale (for example) increased from about 35% of direct charges in 1965 to more than 75% today (that is if you spend $100 on a widget or a technician's salary, you used to have to pay $35 to Yale; today you must pay $75).

I studied the accounts at Yale and managed to raise enough concern among the science faculty to delay some of the cost increases for a few years. (An administrator told me later – with I think a certain grudging admiration – that my interference had cost the university $2,000,000)! But I did not win. Why not – the science faculty does have some power at Yale. However, the science faculty, on the whole, were not deeply interested as most scientists were not seriously affected in the short term by the increased costs. Why was that the case?

University Presidents (Boards of Trustees, etc.) have considerable political power and know how to use it. Know your enemies. The interests of the President of your institution are not coincident with yours. When my old friend Angelo Bartlett Giamatti fell like Lucifer from the heaven of an English Professor's podium to the hell of a University President's office, physicist Ira Bernstein asked Bart if he was henceforth to be known as Diablo rather than Angelo. Like many good jokes, there was a strain of truth in the jest. Through this influence of university leaders and the lobbying of the Association of American Universities which represents those leaders (and not we plebes!), the government has taken the nominal position that it will pay the "full" costs of research where "full" is a jargon word meaning a fair share of the institutional overhead costs. Moreover, again as a consequence of the influence of the private universities, the government assesses the charges in ways designed to minimize confrontations with the science faculty of those schools and minimize the effects of high costs on the competitive position of the private institutions in securing research support.

As a consequence of the institutional pressure, this prima facie reasonable policy of government payment of full costs of research is open to a reading in extreme – and most of the private research universities choose to so read it. So that their high charges does not put them in a weak competitive position, they have successfully applied great pressure on the government funding agencies to establish policies such that only the direct costs of research are considered when an agency must make a cost-benefit assessment. Though the Department of Energy (DOE) and the Na-

tional Science Foundation (NSF), the agencies that support most physics, award total costs in the grants and contracts they negotiate, they are directed to pay any properly audited overhead charges without demur. Indeed, they are directed to avoid any open consideration of indirect cost charge rates. If the University of Michigan assesses a much smaller indirect cost charge on government contracts than Yale (which it does), neither the NSF nor the DOE are supposed to take that extra Yale cost into account in their competitive awarding of funds – though they might well conclude that they could get more research per dollar at Michigan.

The disregard of overhead charges is carried out to an extreme by the National Institutes for Health, and most research universities (especially those with medical schools) receive the bulk of their research moneys from the NIH. An applicant for NIH funds requests only direct costs and is awarded only direct costs. Indirect charges are negotiated separately with the applicants institution by NIH administrators who take no part in the award process. Indeed at one time, all information concerning the indirect cost charges assessed on proposed grants was withheld from the Study Sections that conduct the peer review and effectively award the NIH grants. Consequently, the Study group considers a request for $200,000 for direct research costs from a biologist at Yale (which assesses a $150,000 overhead charge) as being no more expensive than a competitive $200,000 request from a biologist at the University of Michigan (which assesses only about $85,000 in indirect cost charges). Since the larger overhead charge at Yale does not much affect the probability of getting the grant, the Yale biologist is not deeply interested in reducing that overhead. Indeed, at institutions that have a mechanism for putting part of that overhead at the disposal of the scientists, the higher overhead is to their unenlightened self-interest. Of course scientists know that if all overhead charges were smaller, there would be more money for research and they would have a higher probability of getting their grant. But the reduction of the rate of their own institution has little effect unless all institutions are brought to heel.

Though there have been attempts to cap overheads – most recently by a panel led by David Packard and Allan Bromley – these have failed. I believe that less direct methods can serve better to reduce this abuse. I suggest that we ask our political representatives to simply require the funding agencies to consider total costs in the award of research grants and contracts and to encourage the agencies to consider total costs in the cost-benefit analyses which are necessarily a part of ratings of proposals. Such a policy would be of immediate help to those physicists who work at low-cost universities – and most public schools keep overhead rates in bounds. It will hurt me at Yale – but I think only briefly. Briefly, because Yale will reorganize its finances and will choose to compete. And, it will help all of us who wish to see more physics research per dollar.

Rulers of Ur, of Knossos, or of the Department of Energy, know that administration is the mechanism of control. Even as the administration of our affairs is increasing, our freedom of action is diminishing. The still potent battle cry of Academic Freedom largely protects us in the Academy. In the narrow area of the

classroom, the professor is still usually the King (unlike the high school teacher) and, in most schools faculty opinion still carries weight – but not, I think, as much as in the past. Moreover, excepting accreditation groups in education and in engineering (which are marvelously wrong-headed), colleges and universities are not subject to much unwelcome academic oversight.

Research is more closely controlled by administrators (like your speaker) even as the total resources required today for research in physics greatly exceed the personal individual contribution of the scientist. Although auditors can bedevil universities by objecting to the scientist who mingles assets by using one bottle of benzine for two grants – without keeping proper records on the division (and that has happened); and officials acting under the auspices of the Animal Welfare Act can stop all animal research if a few monkeys are not provided with culturally enriched environments (and such actions have been threatened), the great National Research Laboratories suffer more.

The National Laboratories were set up by wise men to be run under contracts from the government to non-governmental entities, thus shielding the laboratories from direct control by the government. Carbon Carbide, the University of Chicago, Associated Universities Incorporated, and the University of California, were contracting officers for Oak Ridge, Argonne, Brookhaven, and Los Alamos, respectively. But in the course of time – and Brookhaven, the youngest of these is 40 years old – this freedom greatly eroded. Administratively, the laboratories are now micro-managed from Washington. (Here, let me emphasize that I do not refer to the scientific program officers who are generally good – and remarkably good in physics).

At Brookhaven, there is, on average, an oversight or auditing group visiting the laboratory every day of the year. Aside from scientific reviews (most of which we welcome and some we invite), our management practices are continually being reviewed and criticized – often enough with little relevance to reality – and the criticism is too often effectively a criticism of levels of effort to be cured by hiring more administrators and increasing administrative costs.

The monetary cost of these reviews is high – I estimate that they cost at least $1,000,000 a year directly at Brookhaven or about $1 for every $100 spent directly on research. Perhaps the accumulated effect on costs of the increased administration required to answer criticisms, is even greater. Perhaps the divergence of the management from truly fundamental concerns, is even more serious. In this, these constant audits have an effect on the laboratories a little like the effect of complex tax laws on businesses. A friend who once built up – and sold – a moderate size chemical company, told me of a conversation he had with a chief executive officer of a large company. When the CEO complained about the tax laws, my friend said, unsympathetically, "quit complaining. Your clever young men will find loopholes so you will get away with as much as you ever did." He was answered to the effect that this was certainly true, but the necessary preoccupation of the brightest men in the company with tax laws led to a serious neglect of the product quality. At BNL

and elsewhere, the time spent by the management on audits reduces the time spent on the efficient management of science. I know that I have sometimes put off decisions of substance because I was busy with external reviews of no great consequence.

I have offered solutions, albeit quixotic, for the other ills I have delineated; what can be done to solve this problem of the micro-management of National Laboratories (and much else in our life) from Washington through a barrage of costly directories and regulations? I suspect that most of us believe that a central authority is necessary for some elements of our society and that local autonomy is best for others. Large experimental groups, notwithstanding, science is still the province of the individual. Somehow, we must convince those whom we choose to govern us, that science is best done through local autonomies.

I have discussed three related problems this morning. If the problems are related, is there any commonality to their solutions? I think so. The thread of "access to information" runs through all possible solutions to those problems. We are clever people, trained to find answers to questions – when we have sufficient data. With sufficient information, we can move towards – perhaps not solutions – but certainly improvements in these matters that are so important to us.

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